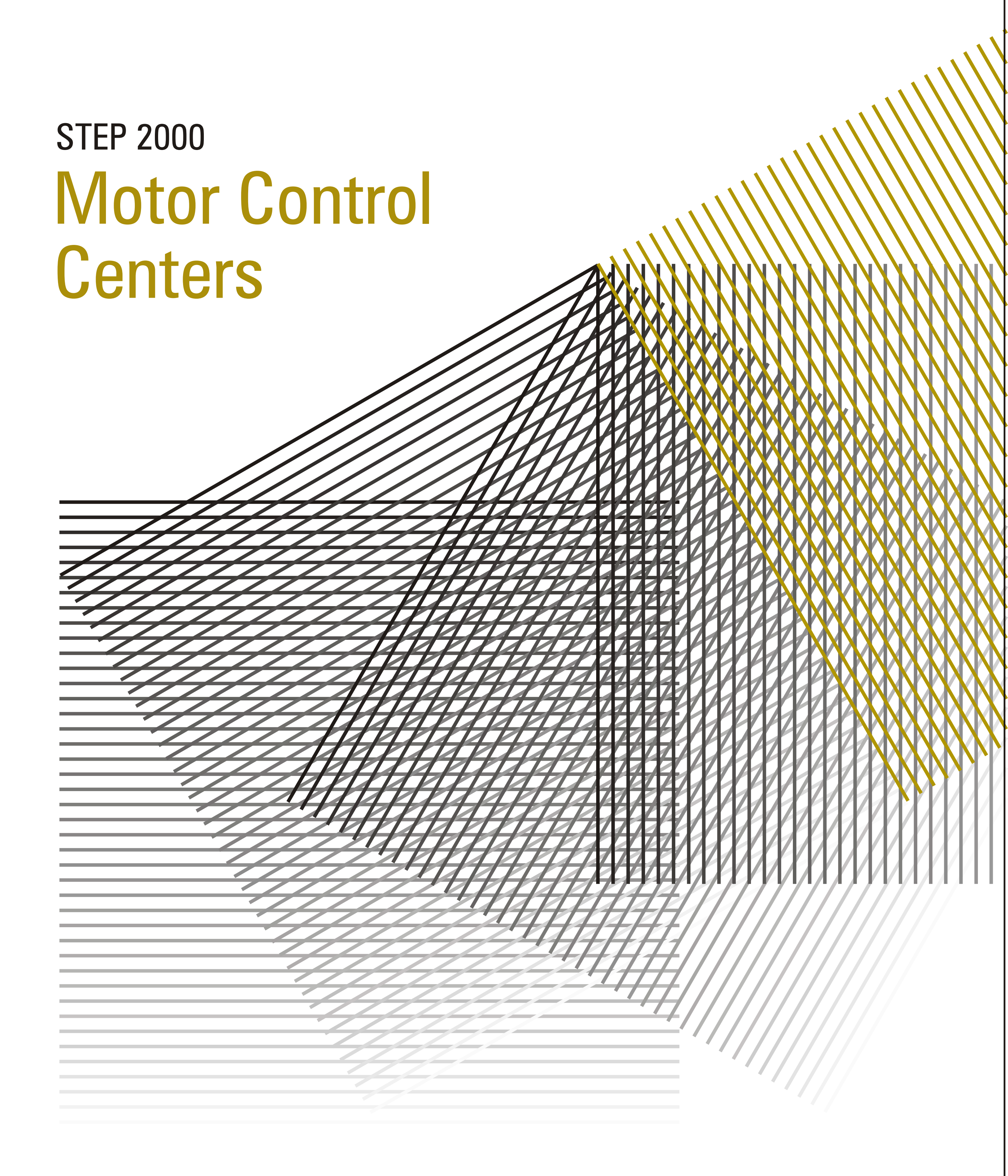
SIEMENS

STEP 2000

# Motor Control Centers



# Table of Contents

# Introduction

Welcome to another course in the STEP 2000 series, **S**iemens **T**echnical **E**ducation **P**rogram, designed to prepare our distributors to sell Siemens Energy & Automation products more effectively. This course covers **Motor Control Centers**.

Upon completion of **Motor Control Centers**, you should be able to:

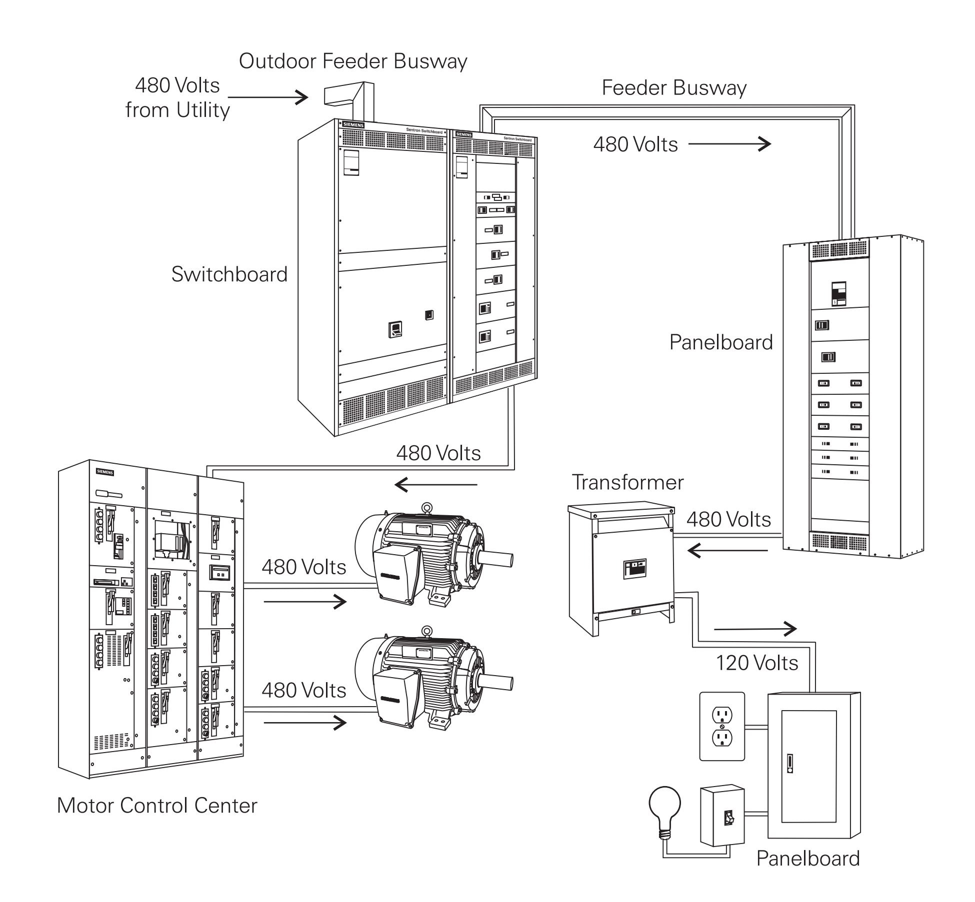
- Explain the role of motor control centers in a distribution system
- Define a motor control center according to NEMA and UL
- Explain the need for circuit protection
- Identify various components of a motor control center
- Explain the difference between the various classifications and types of motor control center wiring
- Explain features of the TIASTAR motor control centers

This knowledge will help you better understand customer applications. In addition, you will be better prepared to describe motor control products to customers. You should complete **Basics of Electricity** and **Basics of Control Components** before attempting **Motor Control Centers**.

If you are an employee of a Siemens Energy & Automation authorized distributor, fill out the final exam tear-out card and mail in the card. We will mail you a certificate of completion if you score a passing grade. Good luck with your efforts.

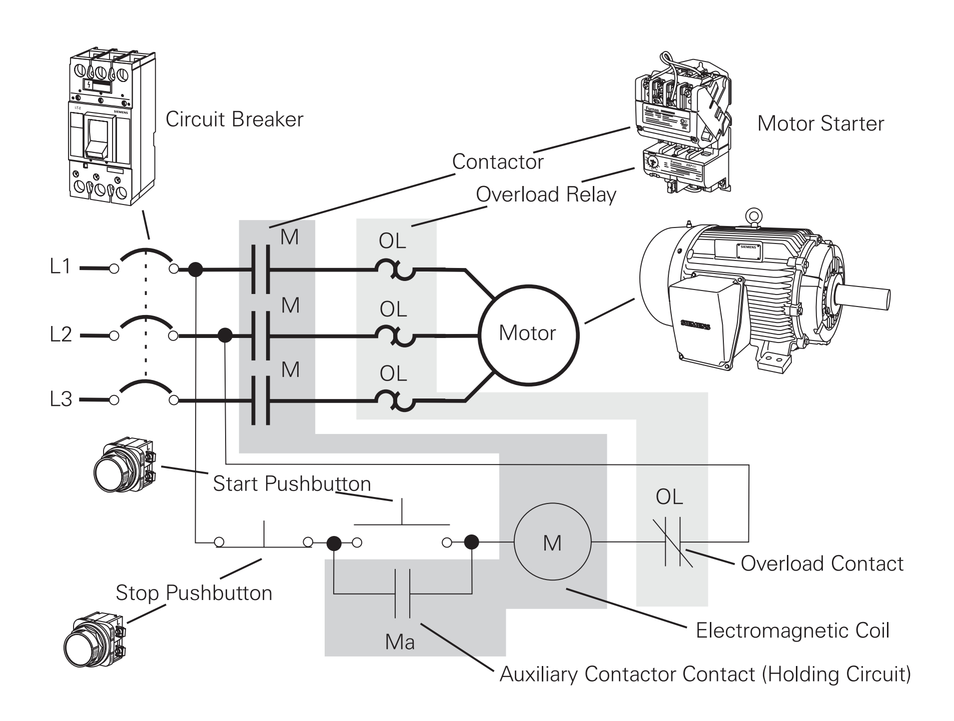
# Motor Control

Distribution systems used in large commercial and industrial applications can be complex. Power may be distributed through various switchboards, transformers, and panelboards. Power distributed throughout a commercial or industrial application is used for a variety of applications such as heating, cooling, lighting, and motor-driven machinery.

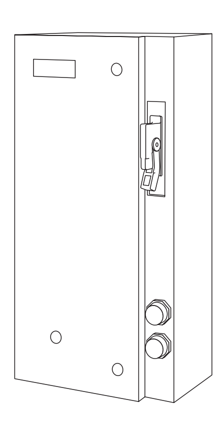


## Basic Motor Control

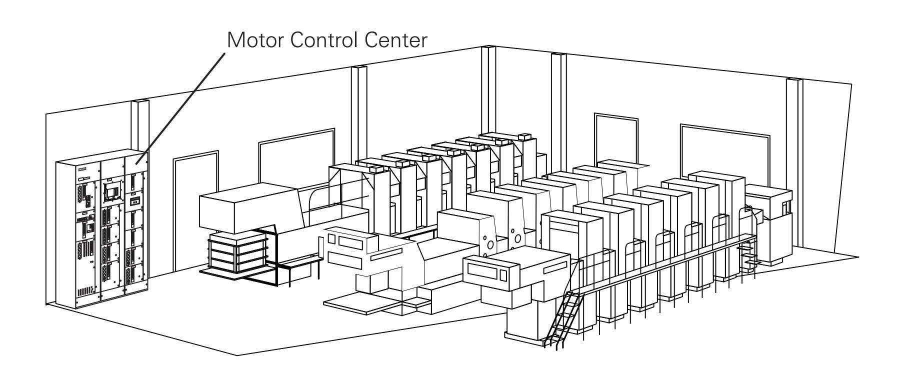
Wherever motors are used, they must be controlled. In **Basics of Control Components** you learned how various control products are used to control the operation of motors. The most basic type of AC motor control, for example, involves turning the motor on and off. This is often accomplished by using a motor starter, which is made up of a contactor and an overload relay. The contactor's contacts are closed to start the motor and opened to stop the motor. This is accomplished electromechanically using start and stop pushbuttons or other pilot devices wired to control the contactor. The overload relay protects the motor by disconnecting power to the motor when an overload condition exists. An overload could occur, for instance, when a conveyor is jammed. Although the overload relay provides protection from overloads, it does not provide short-circuit protection for the wiring providing power to the motor. For this reason, a circuit breaker or fuses are also used.



Typically one motor starter controls one motor. When only a few geographically dispersed AC motors are used, the circuit protection and control components may be located in a panel near the motor.



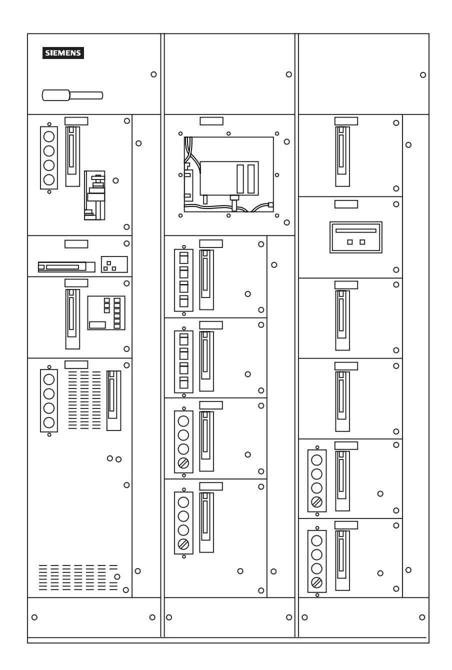
In many commercial and industrial applications quite a few electric motors are required, and it is often desirable to control some or all of the motors from a central location. The apparatus designed for this function is the motor control center (MCC). Motor control centers are simply physical groupings of combination starters in one assembly. A combination starter is a single enclosure containing the motor starter and the fuses or circuit breaker.



## Advantages of Siemens TIASTAR MCCs

TIASTAR™ is the trade name for the Siemens motor control center. Some of the advantages of using TIASTAR are:

- Faster and easier installation and wiring
- Centralized motor control
- Generally less total space is required
- Neat, attractive appearance
- Simplicity in adding special components such as service entrance switches, load centers, and transformers
- Ease of future modifications, such as increasing the size of the starters, adding additional starters, or adding additional vertical sections.

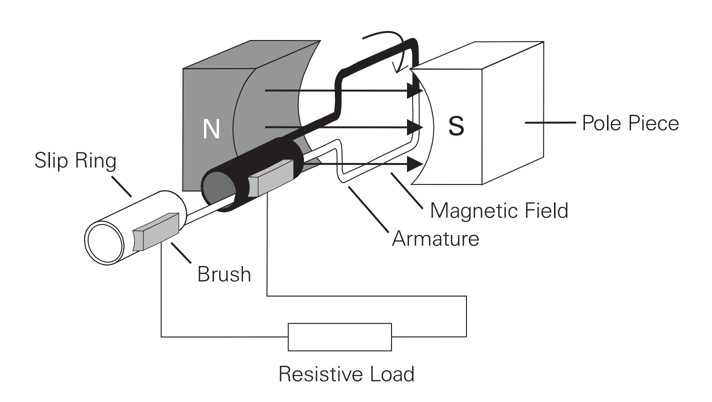




TIASTAR

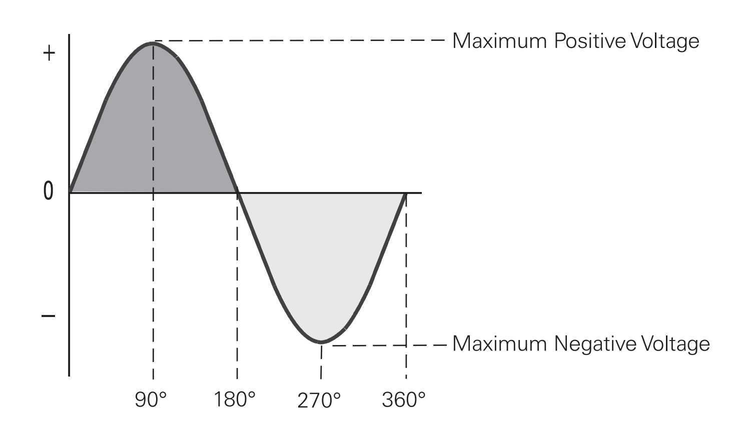
# Power Supplies

The major source of electrical power used by motor control centers is an AC generator located at a power-generating facility. AC generators operate on the theory of electromagnetic induction. This simply means that when conductors are moved through a magnetic field, a voltage is induced into the conductors. A basic generator consists of a magnetic field, an armature, slip rings, brushes, and some type of resistive load. An armature is any number of conductive wires (conductors) wound in loops which rotate through the magnetic field. For simplicity, one loop is shown.



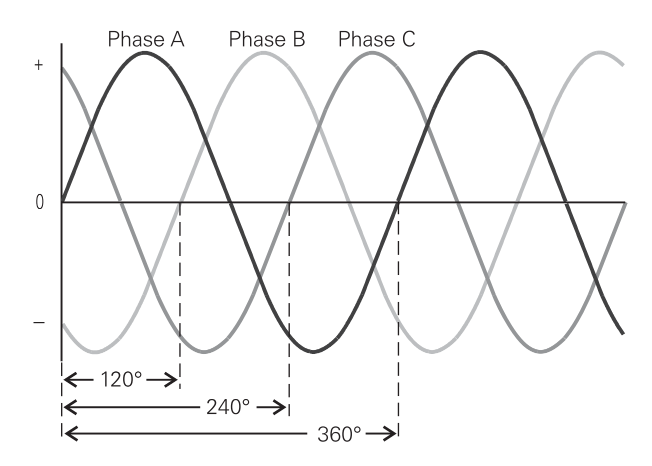

If the rotation of the AC generator were tracked through a complete revolution of 360°, it could be seen that during the first quarter of a revolution voltage would increase until it reached a maximum positive value at 90°. Voltage would decrease during the second quarter of revolution until it reached zero at 180°. During the third quarter of a revolution voltage would increase in the opposite direction until it reached a maximum negative value at 270°. During the last quarter of a revolution voltage would decrease until it reached zero at 360°. This is one complete cycle or one complete alternation between positive and negative.

If the armature of the AC generator were to rotate 3600 times per minute (RPM) we would get 60 cycles of voltage per second, or 60 hertz. Most alternators have more than two poles and one loop of wire. Alternators can have two or three pairs of electromagnetic poles, allowing the AC generator to generate voltage at 60 Hz at slower speeds.

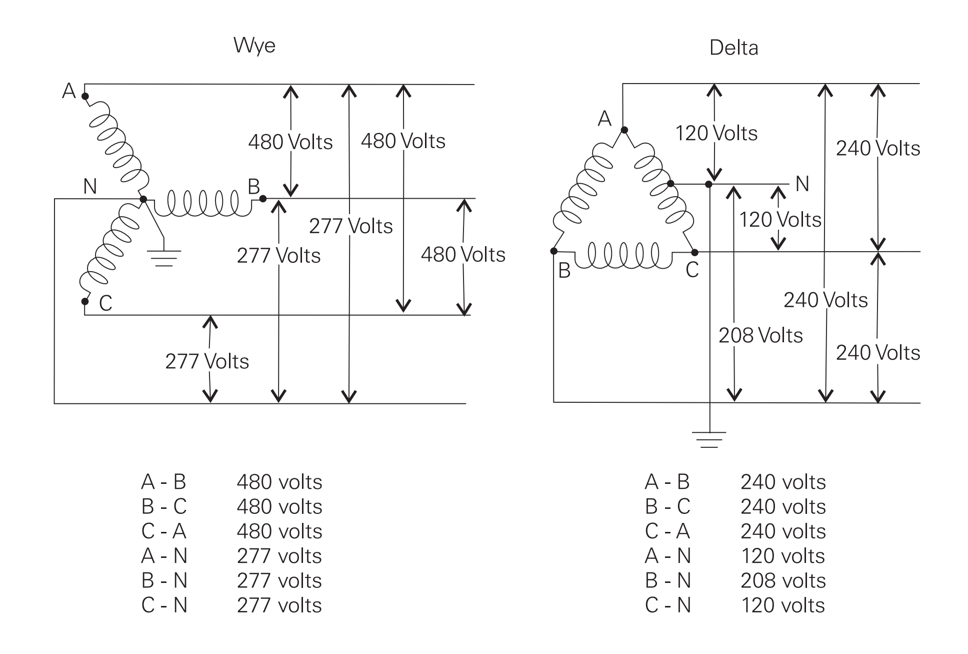



## Three-Phase Voltage

In most large commercial and industrial motor applications three-phase voltage is used. In a three-phase system the generator produces three voltages. Each voltage phase rises and falls at the same frequency (60 Hz in the U.S., 50 Hz in many other countries); however, the phases are offset by 120° from each other.

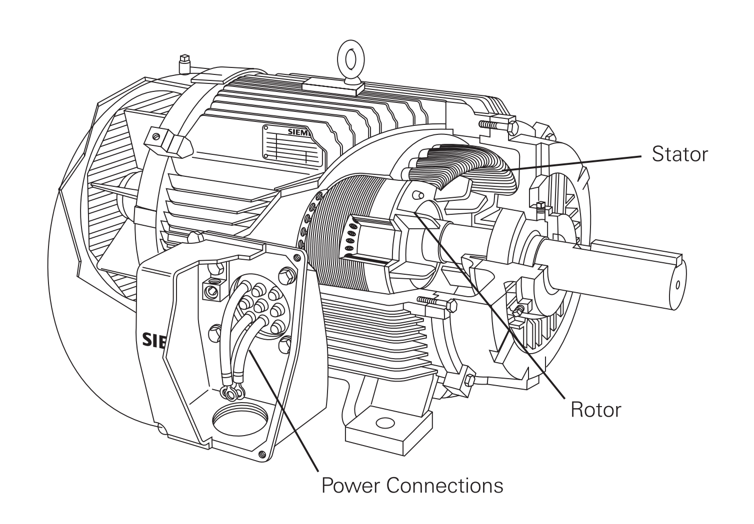


The motor control center receives this power through complex distribution systems which include power distribution lines, transformers, substations, and switchboards. Transformers used with three-phase power require three interconnected coils in both the primary and the secondary. These transformers can be connected in either a wye or a delta configuration. The type of transformer and the actual voltage depend on the requirements and capability of the power company and the needs of the customer. The following illustration shows the secondary of a wye- and delta-connected transformer.

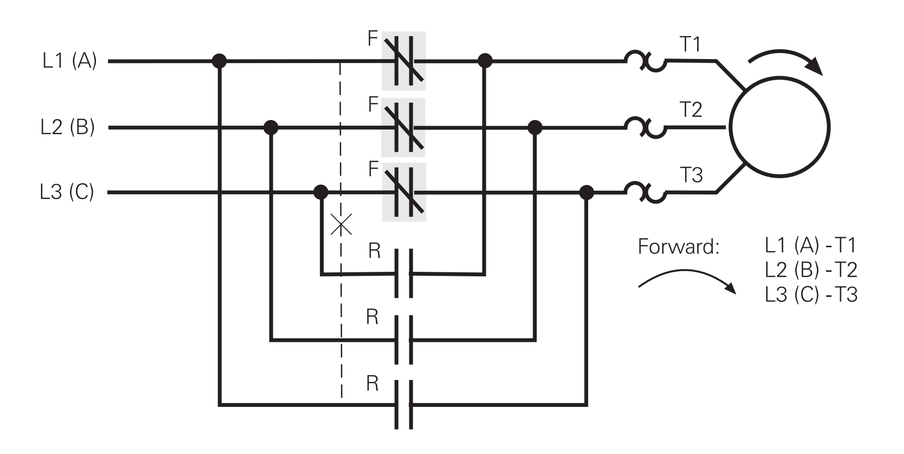



## Motor Rotation

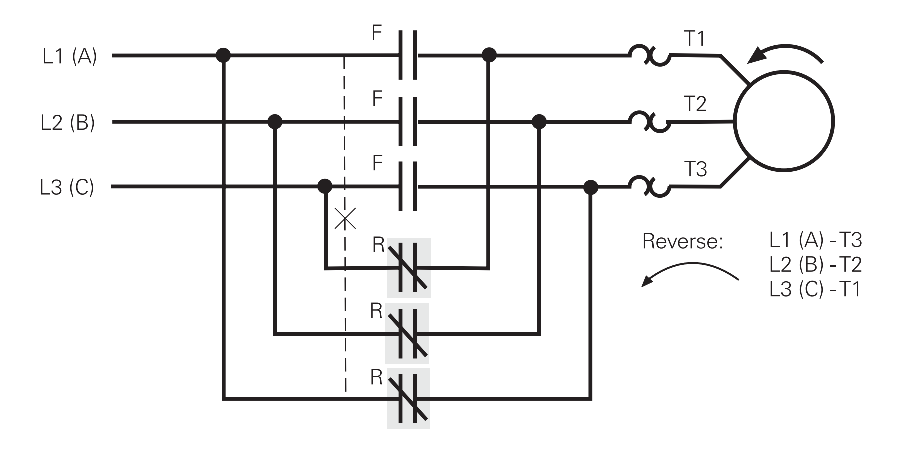
Three-phase voltage is used throughout large commercial and industrial facilities to run AC motors. An AC motor is made up of a stationary member, called a stator, and a rotating member, called a rotor. Three-phase AC power is applied to the stator through the power connections.



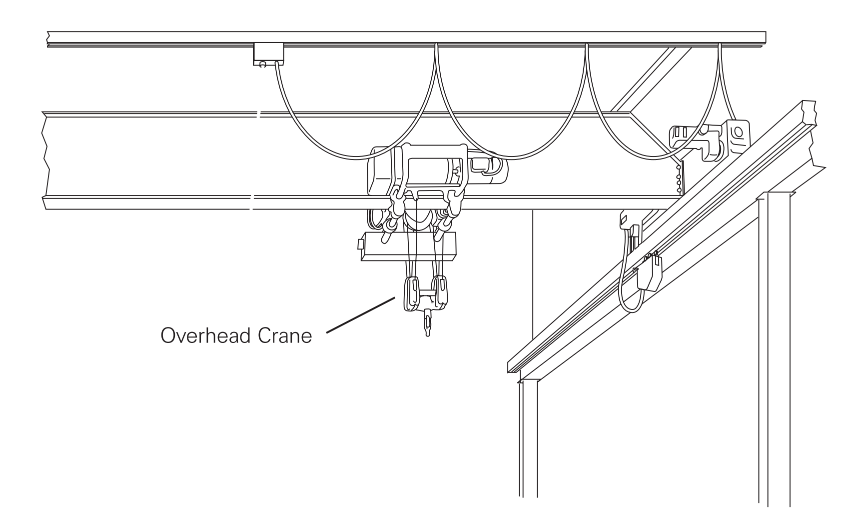
The direction a three-phase AC motor rotates depends on the phase sequence of the incoming power supply. In the following example, L1 (A) is connected to motor lead T1, L2 (B) is connected to motor lead T2, and L3 (C) is connected to motor lead T3. When power is applied through the "F" contacts the motor will turn in a clockwise, or forward direction.




However, by reversing any two of the three power supply leads, the motor will run in the opposite direction. In this example L1 (A) is connected to motor lead T3, L2 (B) is connected to motor lead T2, and L3 (C) is connected to motor lead T1(L1 and L3 have been reversed). When power is applied through the "R" contacts the motor will run in the counterclockwise, or reverse direction.



Many applications are designed for forward and reverse operation. An overhead crane, for example, might use the forward direction to raise the crane and reverse direction to lower the crane.




It should be noted that it is not possible to reverse the direction of rotation on some applications. The consequences of running a motor in the reverse direction on an application designed to run only in the forward direction can be disastrous, resulting in equipment damage and possibly injury or loss of life.

## Review 1

1. Which of the following is an advantage of using a motor control center?

   a. Faster and easier installation
   b. Simplicity in adding special components
   c. Ease of future modifications
   d. All the above

2. ____________ is the trade name for the motor control center manufactured by Siemens.

3. In most large commercial and industrial motor applications ____________ -phase voltage is used.

4. Motor rotation of a three-phase AC motor can be reversed by reversing any ____________ of the three power-supply leads.

# Design Standards

Although several organizations are involved in establishing standards for the design, construction, and application of motor control centers, the primary standards are established by UL, NEMA, and the National Electrical Code® (NEC®). The following organizations have established standards which may be applied to motor control centers. It is beyond the scope of this course to cover every standard; however, reference will be made throughout the course to many important standards with which Siemens motor control centers comply.

**UL**

Underwriters Laboratories (UL) is a private company that is nationally recognized as an independent testing laboratory. UL tests products for safety and products that pass UL tests can carry a UL mark. Siemens motor control centers are designed to UL 845 standards.

**NEMA**

The National Electrical Manufacturers Association (NEMA) is an organization that, among other things, develops standards for electrical equipment.

**NEC**

The National Fire Protection Association (NFPA) is a nonprofit organization which publishes the *National Electrical Code®* (*NEC®*). The intent of the *NEC®* is to describe safe electrical practices.

**ANSI**

The American National Standards Institute (ANSI) is a nongovernmental organization that facilitates the development of standards by establishing a consensus among qualified groups.

**IEEE**

The Institute of Electrical and Electronic Engineers (IEEE) is an organization open to individual membership and provides a variety of services for its members. It also develops numerous standards for electrical and electronic equipment and practices.

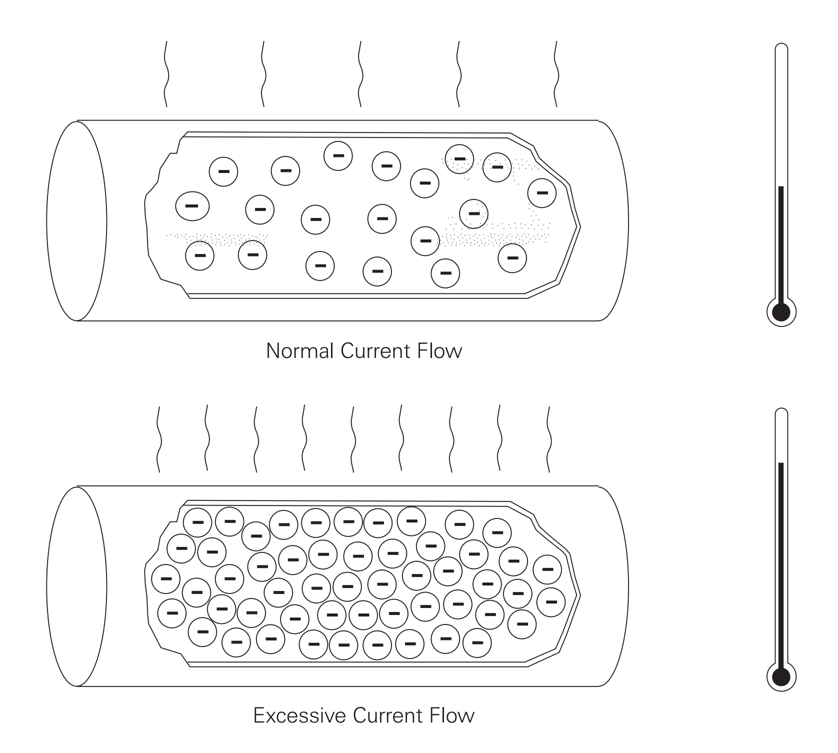
**IEC**

The International Electrotechnical Commission (IEC) is an organization based in Geneva, Switzerland, with over 50 member nations. IEC writes standards for electrical and electronic equipment practices.

# Need for Circuit Protection

**Current and Temperature**

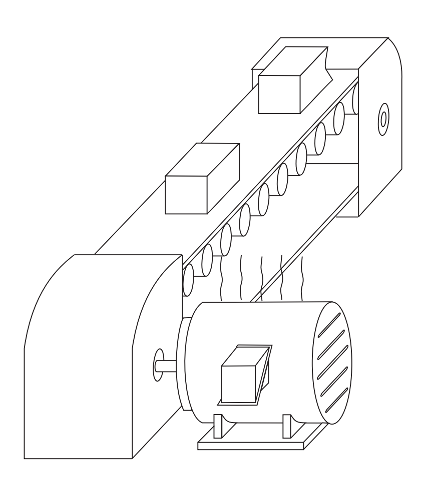
Current flow in a conductor always generates heat. The greater the current flow in any one size conductor, the hotter the conductor. Excess heat is damaging to electrical components and conductor insulation. For that reason conductors have a rated, continuous current-carrying capacity or ampacity. Overcurrent protection devices, such as fuses, are used to protect conductors from excessive current flow.




Excessive current is referred to as overcurrent. The *National Electrical Code®* defines overcurrent as *any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault* (Article 100-definitions).

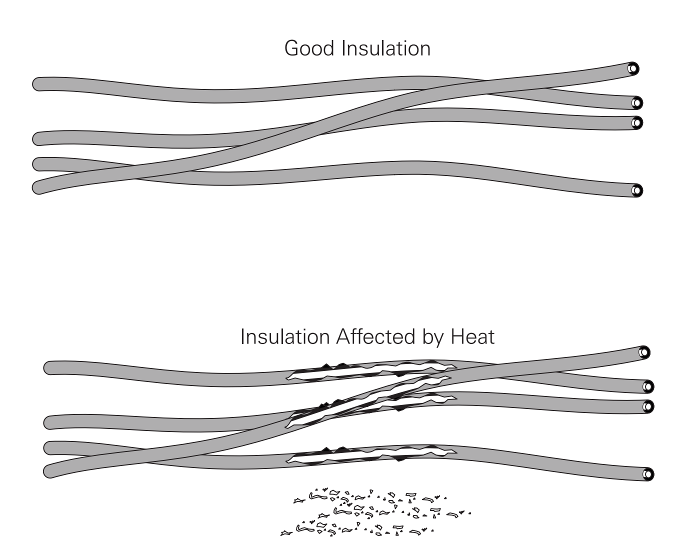
## Overloads

An overload occurs when too many devices are operated on a single circuit, or a piece of electrical equipment is made to work harder than it is rated design. For example, a motor rated for 10 amperes may draw 20, 30, or more amperes in an overload condition. In the following illustration, a package has become jammed on a conveyor, causing the motor to work harder and draw more current. Because the motor is drawing more current, it heats up. Damage will occur to the motor in a short time if the problem is not corrected or if the circuit not is shut down by the overcurrent protector.



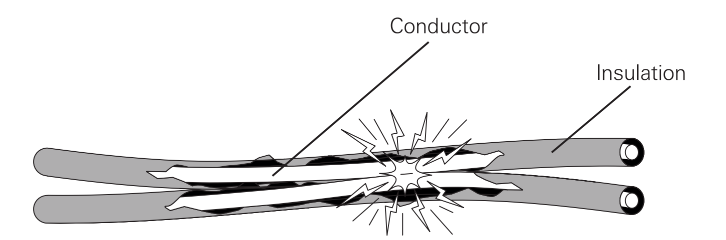
## Conductor Insulation

Motors, of course, are not the only devices that require circuit protection for an overload condition. Every circuit requires some form of protection against overcurrent. Heat is one of the major causes of insulation failure of any electrical component. High levels of heat to insulated wire can cause the insulation to breakdown, melt, or flake off, exposing conductors.



## Short Circuits

When two bare conductors touch, a short circuit occurs. When a short circuit occurs, resistance drops to almost zero. Short circuit current can be thousands of times higher than normal operating current.




Ohm's Law demonstrates the relationship of current, voltage, and resistance. For example, a 240 volt motor with 24 Ω (ohms) of resistance would normally draw 10 amperes of current.

$$I = \frac{E}{R}$$

$$I = \frac{240}{24}$$

$$I = 10 \text{ amperes}$$

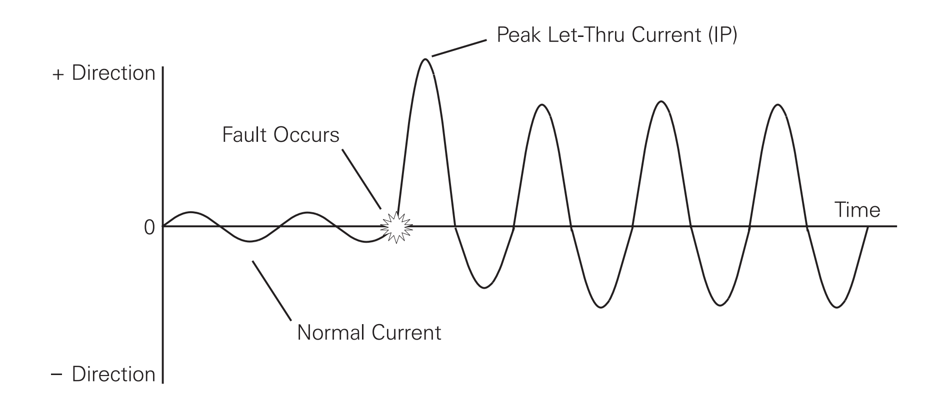
When a short circuit develops, resistance drops. If resistance drops to 24 milliohms, current will be 10,000 amperes.

$$I = \frac{240}{0.024}$$

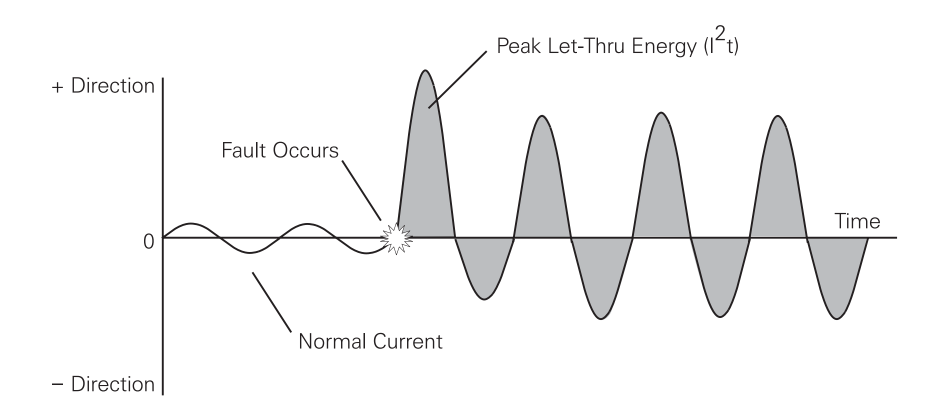
$$I = 10{,}000 \text{ amperes}$$

## Short-Circuit Current on Unprotected Electrical Circuits

When a short circuit occurs, current will continue to flow in an unprotected electrical circuit. The peak short-circuit current of the first cycle is the greatest and is referred to as peak let-thru current ($I_P$). The force of this current can cause damage to wires, switches, and other electrical components of a circuit.

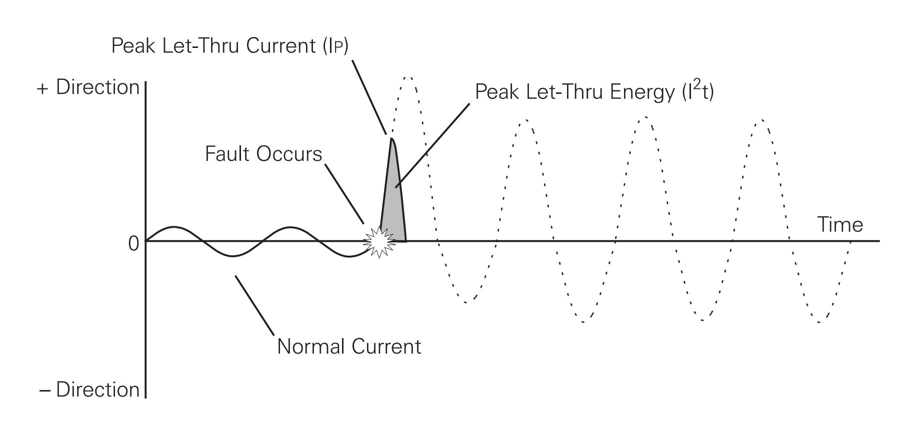



There is also energy let-thru ($I^2t$). This destructive thermal force is capable of melting conductors.




## Short-Circuit Current on Protected Electrical Circuits

A properly used, overcurrent-protection device will open the circuit quickly, limiting peak let-thru current ($I_P$) and energy ($I^2t$).



**Article 240**

Circuit protection would be unnecessary if overloads and short circuits could be eliminated. Unfortunately, overloads and short circuits do occur.

Article 240 of the *NEC®* covers overcurrent protection. You are encouraged to become familiar with this material. Article 240.1 states that:

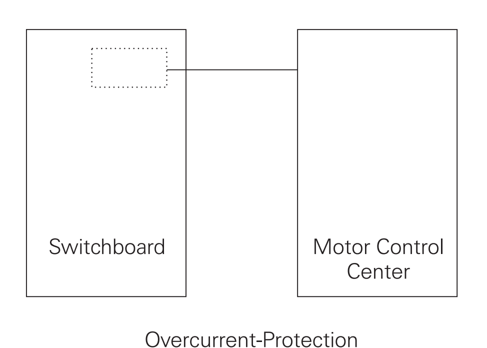
*Overcurrent protection for conductors and equipment is provided to open the circuit if the current reaches a value that will cause an excessive or dangerous temperature in conductors or conductor insulation.*

**Article 430.94**

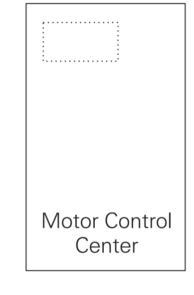
The *National Electrical Code®* requires overcurrent protection for motor control centers. *NEC®* article 430.94 states:

*Motor control centers shall be provided with overcurrent protection in accordance with Parts I, II, and IX of Article 240. The ampere rating or setting of the overcurrent protective device shall not exceed the rating of the common power bus. This protection shall be provided by (1) an overcurrent-protective device located ahead of the motor control center or (2) a main overcurrent-protective device located within the motor control center.*

There are two ways Article 430.94 can be met. An overcurrent-protection device can be installed ahead of the motor control center. A switchboard, for example, located upstream of the motor control center may contain the overcurrent-protection device for the motor control center. The second way to meet this requirement is to install a main over-current protection device within the motor control center.




Overcurrent-Protection Device Ahead of MCC



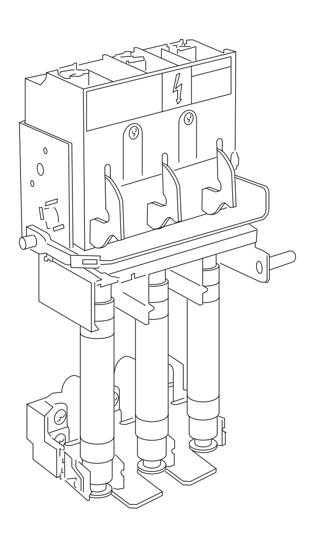

Main Overcurrent-Protection Device Located in MCC

# Overcurrent-Protection Devices

An overcurrent-protection device must be able to recognize the difference between an overcurrent and short circuit and respond in the proper way. Slight overcurrents can be allowed to continue for some period of time; but as the current magnitude increases, the protection device must open faster. Short circuits must be interrupted instantly.

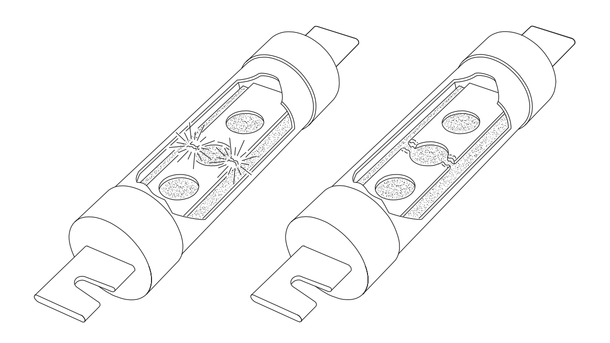
**Fusible Disconnect Switch**

A fusible disconnect switch is one type of device used to provide overcurrent protection. Properly sized fuses located in the switch open the circuit when an overcurrent condition exists.



**Fuse**

A fuse is a one-shot device. The heat produced by overcurrent causes the current carrying element to melt open, disconnecting the load from the source voltage.



## Nontime-Delay Fuses

Nontime-delay fuses provide excellent short-circuit protection. When an overcurrent occurs, heat builds up rapidly in the fuse. Nontime-delay fuses usually hold 500% of their rating for approximately one-fourth second, after which the current-carrying element melts. This means that these fuses should not be used in motor circuits which often have inrush currents greater than 500%.

## Time-Delay Fuses

Time-delay fuses provide overload and short-circuit protection. Time-delay fuses usually allow five times the rated current for up to ten seconds to allow motors to start.

## Fuse Classes

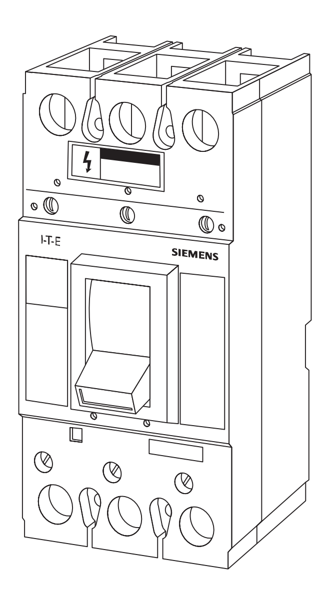
Fuses are grouped into classes based on their operating and construction characteristics. Each class has an ampere interrupting capacity (AIC) which is the amount of fault current they are capable of interrupting without destroying the fuse casing. Fuses are also rated according to the maximum continuous current and maximum voltage they can handle. Underwriters Laboratories (UL) establishes and standardizes basic performance and physical specifications to develop its safety-test procedures. These standards have resulted in distinct classes of low-voltage fuses rated at 600 volts or less. The following chart lists the fuse class and its AIC rating.

| Class | Voltage Rating | Ampere Rating | Interrupting Rating (Amps) | Sub Classes | UL Standard |
|---|---|---|---|---|---|
| **R** | 250, 600 | 0-600 | 200,000 | RK1 and RK5 | UL 248 12 |
| **J** | 600 | 0-600 | 200,000 | | UL 248 B |
| **L** | 600 | 601-6000 | 200,000 | | UL 248 10 |
| **CC** | 600 | 0-30 | 200,000 | | UL 248 4 |

## Circuit Breakers

Another device used for overcurrent protection is a circuit breaker. The *National Electrical Code ®* defines a circuit breaker as *a device designed to open and close a circuit by nonautomatic means, and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its rating*.

Circuit breakers provide a manual means of energizing and de-energizing a circuit. In addition, circuit breakers provide automatic overcurrent protection of a circuit. A circuit breaker allows a circuit to be reactivated quickly after a short circuit or overload is cleared. Since it merely needs to be reset there is nothing to replace after a short circuit.




## Ampere Rating

Like fuses, every circuit breaker has a specific ampere, voltage, and fault-current interruption rating. The ampere rating is the maximum continuous current a circuit breaker can carry without exceeding its rating. As a general rule, the circuit breaker ampere rating should not exceed the conductor ampere rating. For example, if the conductor is rated for 20 amps, the circuit breaker rating should not exceed 20 amps. Siemens breakers are rated on the basis of using 60° C or 75° C conductors. This means that even if a conductor with a higher temperature rating were used, the ampacity of the conductor must be figured on its 60° C or 75° C rating.

There are some specific circumstances when the ampere rating is permitted to be greater than the current-carrying capacity of the circuit. For example, motor and welder circuits can exceed conductor ampacity to allow for inrush currents and duty cycles within limits established by *NEC®*.

Generally the ampere rating of a circuit breaker is selected at 125% of the continuous load current. This usually corresponds to the conductor ampacity which is also selected at 125% of continuous load current. For example, a 125 amp circuit breaker would be selected for a load of 100 amps.

**Voltage Rating**

The voltage rating of the circuit breaker must be at least equal to the supply voltage. The voltage rating of a circuit breaker can be higher than the supply voltage, but never lower. For example, a 480 VAC circuit breaker could be used on a 240 VAC circuit. A 240 VAC circuit breaker could not be used on a 480 VAC circuit. The voltage rating is a function of the circuit breaker's ability to suppress the internal arc that occurs when the circuit breaker's contacts open.

**Fault-Current Interrupting Rating**

Circuit breakers are also rated according to the level of fault current they can interrupt. When applying a circuit breaker, one must be selected to sustain the largest potential short-circuit current which can occur in the selected application. Siemens circuit breakers have interrupting ratings from 10,000 to 200,000 amps.

**Review 2**

1. ____________ ____________ is a private company that is nationally recognized as an independent testing laboratory.

2. The ____________ ____________ ____________ ____________ publishes the *National Electrical Code®*

3. Class R fuses have an interupting rating of ____________ amps.

4. Installing an overcurrent protective device ahead of an MCC or installing a main overcurrent protective device within an MCC are two methods of meeting *NEC®* Article ____________ .

**NEMA Definition**

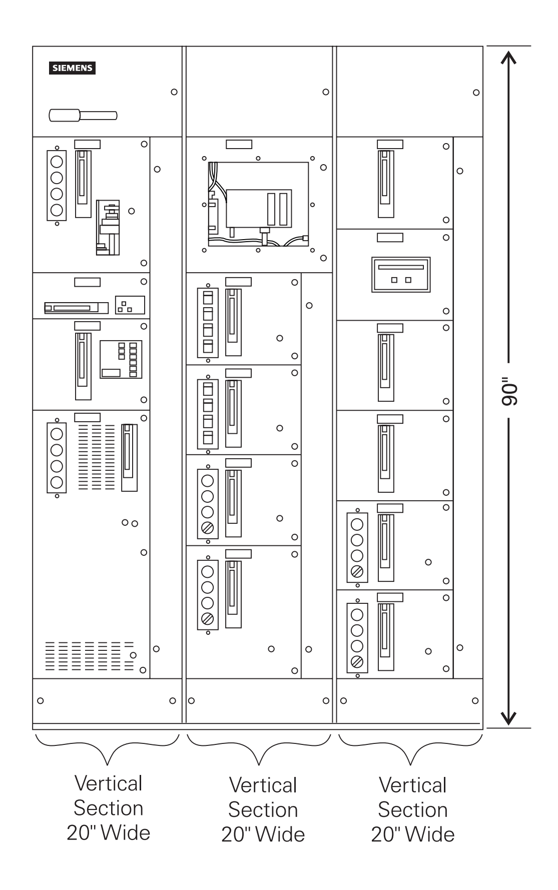
NEMA defines a motor control center in ICS-2-322 as being *a floor-mounted assembly of one or more enclosed vertical sections having a horizontal common power bus and principally containing combination motor control units. These units are mounted one above the other in the vertical sections. The sections may incorporate vertical buses connected to the common power bus, thus extending the common power supply to the individual units. Units may also connect directly to the common power bus by suitable wiring.*

According to the NEMA definition, motor control centers:

- Are floor-mounted assemblies
- Have one or more enclosed vertical sections
- Have a common horizontal power bus
- May incorporate vertical buses connected to the common bus
- Principally contain combination motor control units

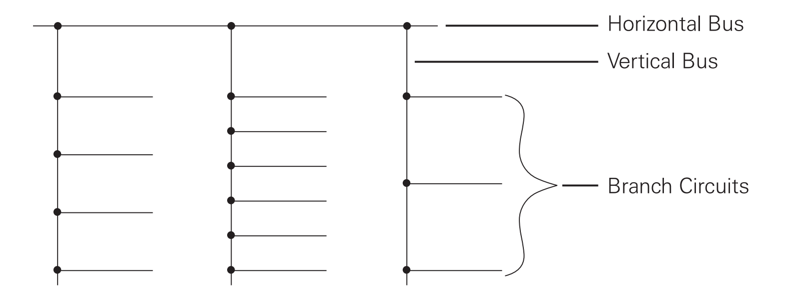
## Vertical Sections

The motor control center is made up of a steel structure to contain the combination motor control units, wireways, internal wiring, and bus bars. From the NEMA definition it can be seen that a motor control center is a floor-mounted assembly made up of enclosed vertical sections. One vertical section may stand alone as a complete motor control center, or several sections may be bolted and bussed together. Vertical sections are generally 20” wide by 90” high.

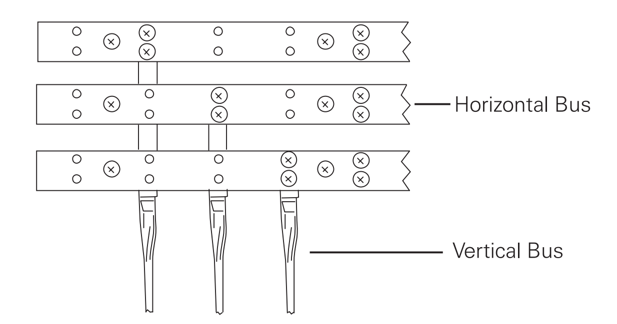



## Horizontal and Vertical Bus

A bus is a conductor that serves as a common connection for two or more circuits. It is represented schematically by a straight line with a number of connections made to it.



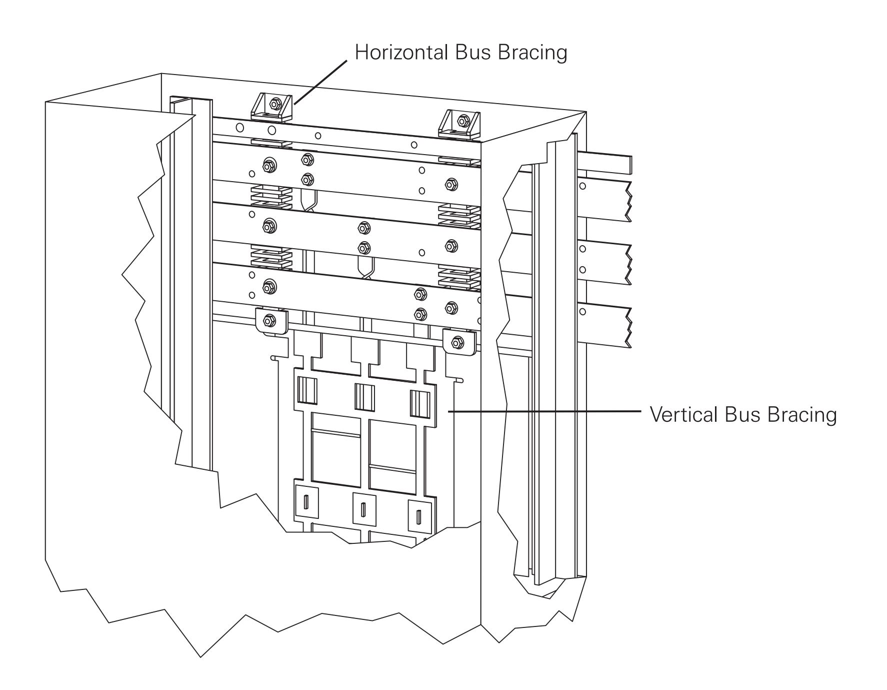
In power circuits, such as motor control centers, a bus is made of a heavy-duty metal bar. These bars provide power to each of the combination motor control units. The vertical bus is connected to a corresponding horizontal bus and is isolated from the other bus bars.




**Bus Support**

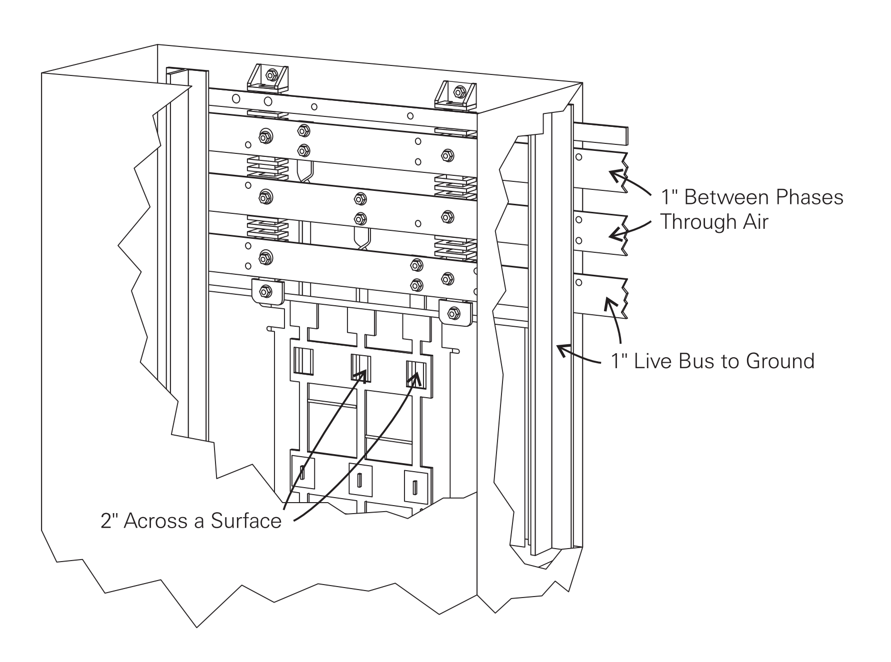
The *NEC*® discusses bus bars used in motor control centers in Article 430.97(A), which states that *busbars shall be protected from physical damage and be held firmly in place*.

Bus bracing is very important due to the increased available fault current in today's modern power systems. In this example of a Siemens motor control center the horizontal bus is firmly bolted to molded supports. The vertical bus is either encased in a molded support or supported by bus brackets, depending on which MCC is supplied.



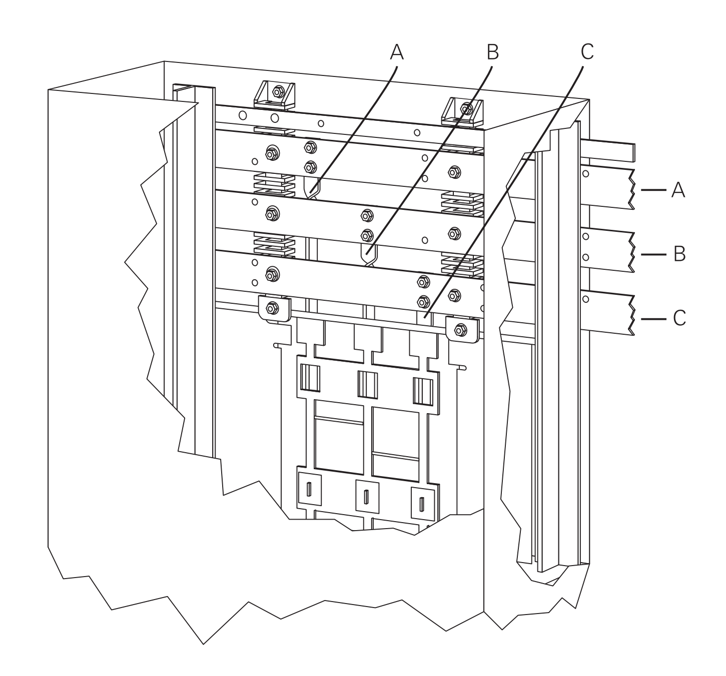
## Bus Spacing

In addition, *NEC*® Table 430.97 requires 1" of clearance between a live bus and ground, 1" of clearance between phases through air, and 2" of clearance across a surface for voltages over 250 volts. These spacings are used throughout the horizontal and vertical bus in the MCC.

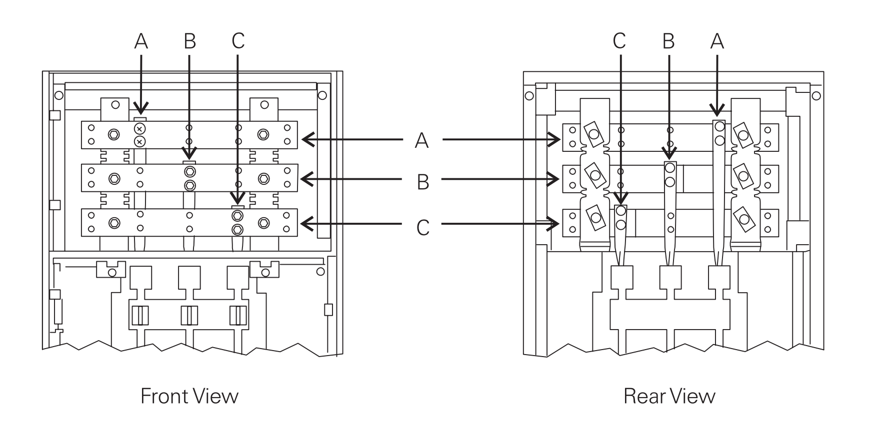



## NEMA Phase Arrangement

NEMA requires bus bars to have phases in sequence so that an installer can have the same fixed phase arrangement at each termination point in any motor control center. The following diagram illustrates accepted NEMA phase arrangements. It is possible to have a non-NEMA phase sequence; however, this would have to be clearly marked.

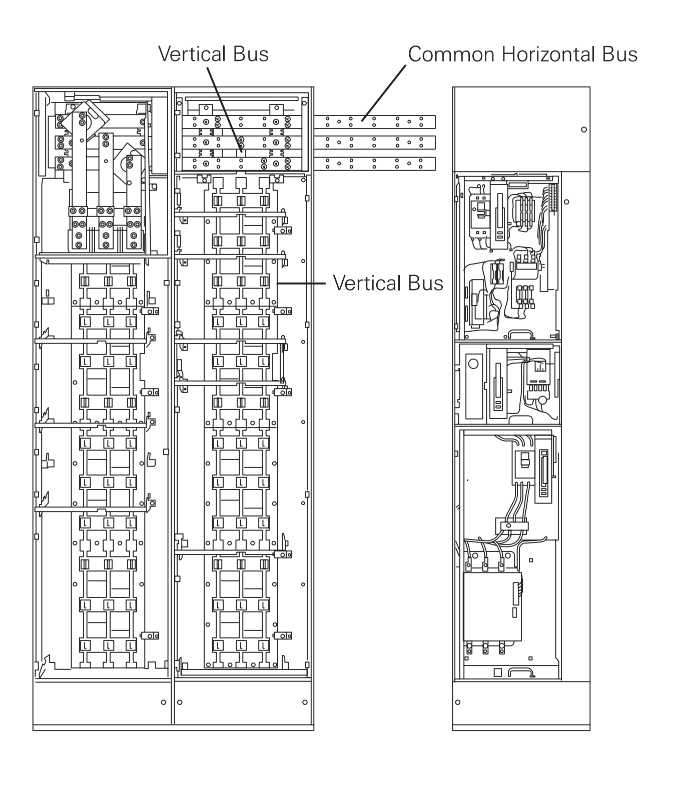


It should be noted that the NEMA phase arrangement illustrated in the previous drawing is viewed from the front. The vertical bus bars appear to be in reverse order when viewed from the rear. Some motor control centers can have devices installed on the front and rear of the motor control center.

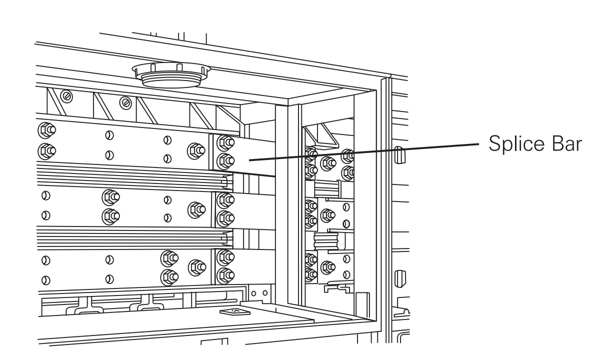



**Shipping Splits**

When a motor control center is made up of more than one vertical section, the sections are assembled together with a common top- and bottom-frame assembly. For shipping, this assembly can consist of a maximum of four 20” wide vertical sections (80” maximum). Several assemblies can be bolted and bussed together at the installation site to form a complete lineup. In the following illustration one vertical section has been moved to show the horizontal bus. In this case each horizontal bus bar is a single continuous piece that extends through all three sections.



When there are more than four sections or the customer specifies a split between two vertical sections a splice kit between the horizontal bus bars can be installed.

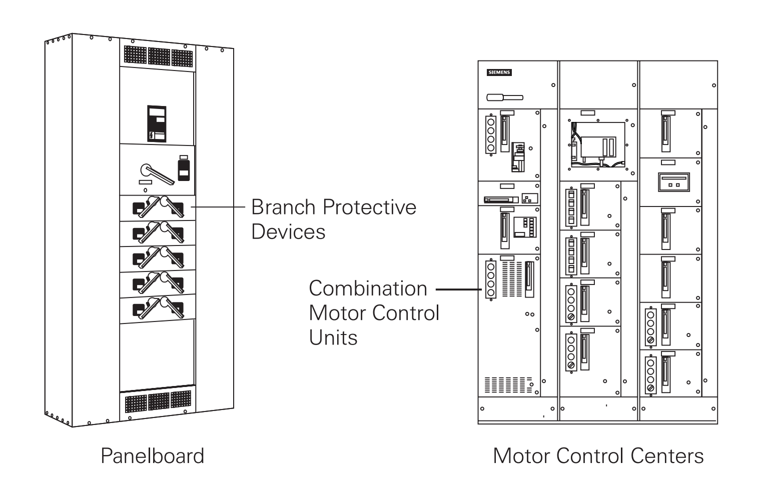



**Combination Motor Control Units**

Motor control centers are distinguished from other distribution devices, such as panelboards and switchboards, in that motor control centers principally contain combination motor control units. Panelboards and switchboards principally contain branch circuit-protection devices such as circuit breakers and fusible disconnects.

**Underwriter's Laboratory**

UL defines a motor control center similarly to NEMA. UL will allow use of branch circuit-protection units in a motor control center provided their use does not make up a major portion of the motor control center. In addition, UL 845 allows the use of associated auxiliary devices and panelboards to be part of a motor control center. Often, lighting transformers, panelboards, and load centers are incorporated in motor control centers.

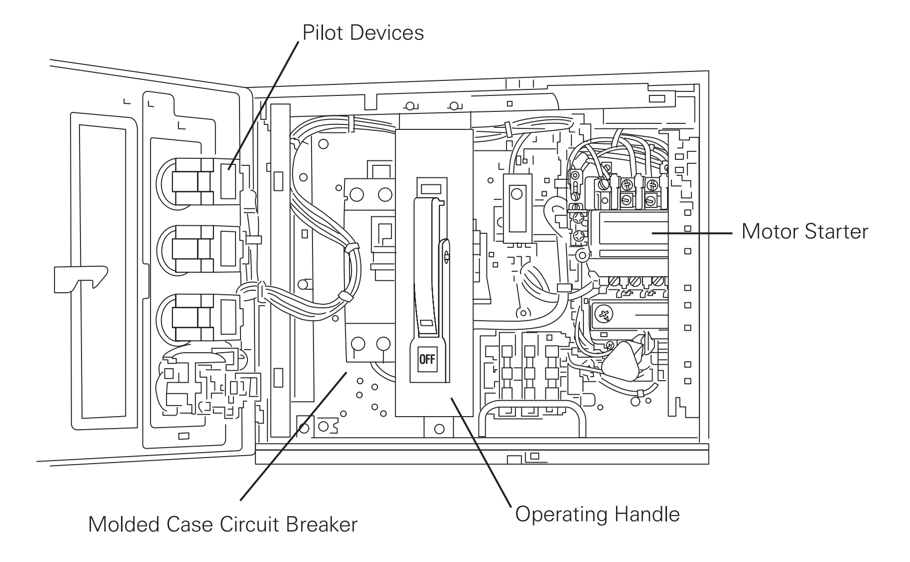


# Combination Motor Control Units

Motor control centers principally contain combination motor control units. NEMA ICS-1-322 states that . . .

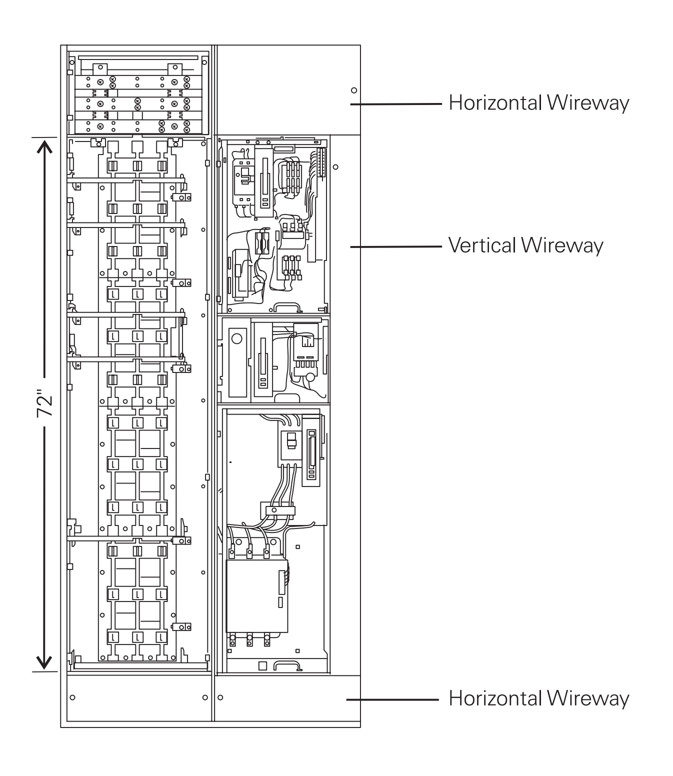
*A combination motor control unit shall include externally operable circuit disconnecting means, branch-circuit overcurrent protection, and a magnetic motor controller with associated auxiliary devices when used. The disconnecting means and branch-circuit overcurrent protection shall consist of a fusible disconnecting device or circuit breaker. If the latter is used, it shall either be an inverse time (thermal-magnetic or dual magnetic) or an instantaneous magnetic type. The motor controller shall include motor and branch-circuit protection unless equivalent protection is otherwise provided.*

A combination motor control unit takes all the elements required to control an AC motor and combines them into one unit. The combination motor control unit in the following example uses a molded case circuit breaker to provide circuit disconnecting means and branch-circuit overcurrent protection. The circuit breaker is opened and closed using the operating handle located on the front of the unit. The magnetic motor starter is used to start and stop an AC motor and provide overcurrent protection for the motor. Pilot devices, located on the door, serve to provide an operator means to start and stop the motor as well as provide visual indication of the motor's status.



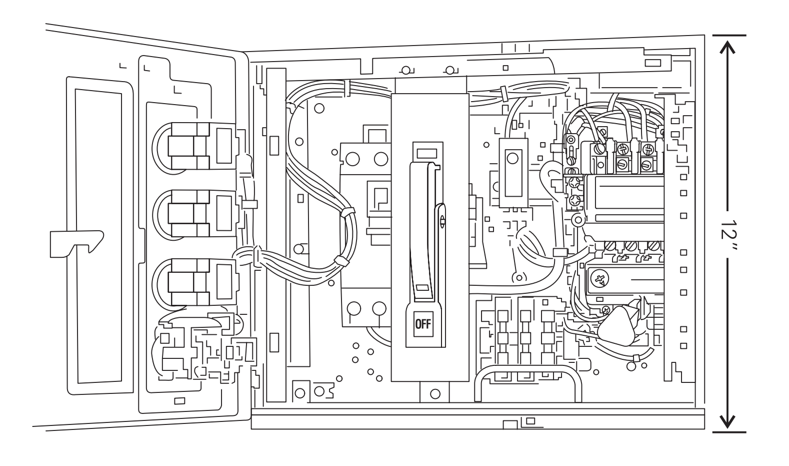
## Vertical Space

Most vertical sections provide 72" of vertical space for the combination motor control units. As many sections as needed will be assembled together to contain all of the required combination motor control units and other equipment. Wireways run horizontally across the top and bottom of all of the sections. A vertical wireway is provided in each vertical section.



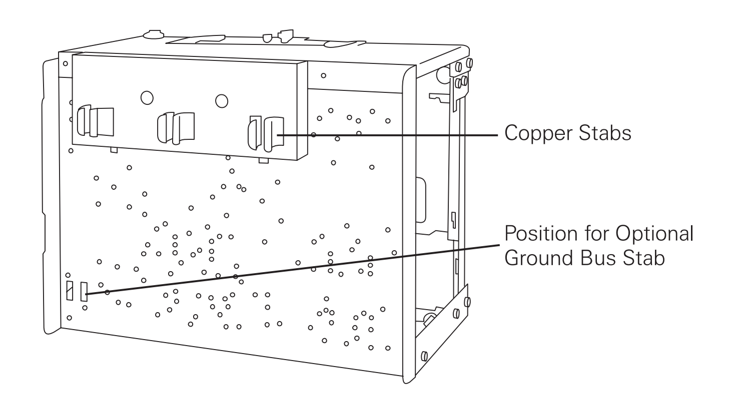

## Dimensions

Combination motor control units are designed to fit into modular compartments. Typically, the minimum height of a combination motor control unit is 12," increasing in 6" increments (12," 18," 24," 30," up to 72") as needed. Six combination motor control units that are 12" high will fit in 72" of vertical space.

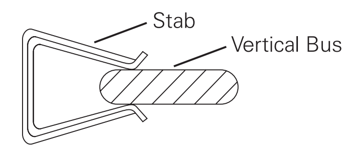


## Installation and Removal

To simplify installation and removal, combination motor control units are provided with self-aligning copper stabs on the back of the control unit. An optional ground bus stab is used when a vertical ground bus is supplied. A fixed mounting is used when the unit is phsically too large for stabs or rated for greater than 250 amps.

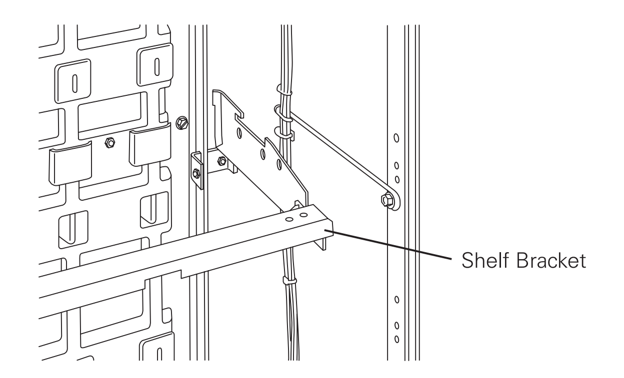



These stabs engage the vertical bus bars, making the electrical connection to the control unit. Siemens incorporates a flat vertical bus bar to ensure positive connection between the stab and the bus bar.




## Unit Supports

Combination motor control units are supported in the motor control center on shelf brackets. The brackets can be easily moved to accommodate different size units. The brackets guide the combination motor control unit to assure positive engagement with the vertical bus.



## Review 3

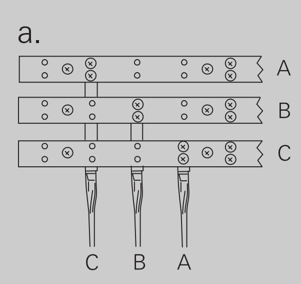
1. Which of the following is <u>not</u> a part of the NEMA definition for motor control centers?

   a. Floor-mounted assembly
   b. Allowance for branch-circuit protection units
   c. Common horizontal bus
   d. Principally contains combination motor control units

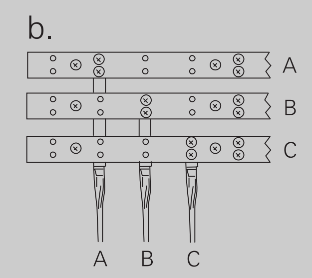
2. The maximum shipping width of a motor control center is ___________ inches.

3. Which of the following illustrates proper NEMA phase arrangement, as viewed from the front?

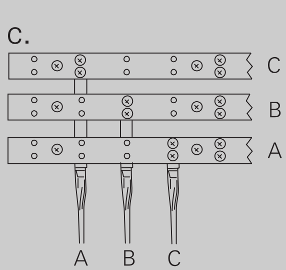
a.



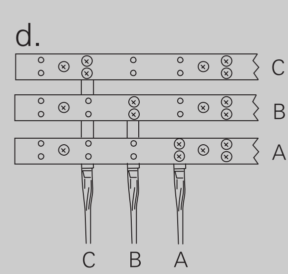

b.




c.




d.




4. A distinguishing feature of motor control centers from panelboards is that motor control centers ___________ .

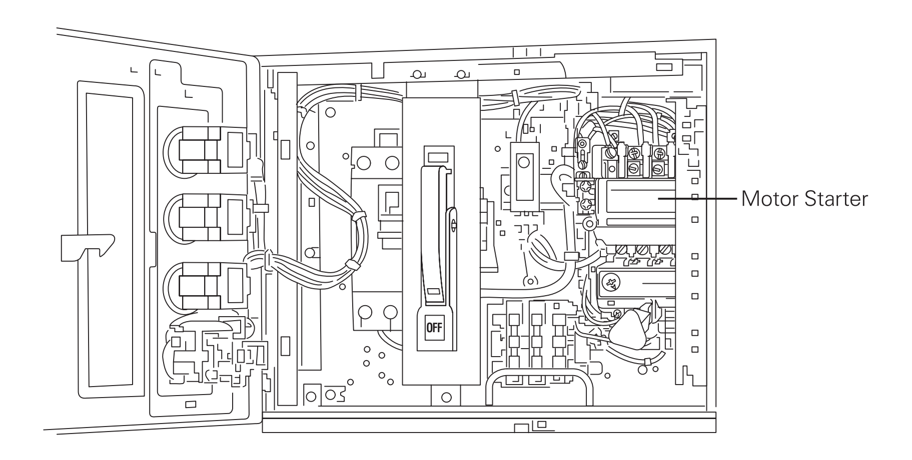
   a. principally contain combination motor control units
   b. principally contain branch-circuit protection devices
   c. utilize both a horizontal and a vertical bus
   d. connect to three-phase power

5. According to NEMA's definition, which of the following is not part of a combination motor control unit?

   a. externally operable circuit disconnecting means
   b. common horizontal bus
   c. branch-circuit overcurrent protection
   d. magnetic motor controller

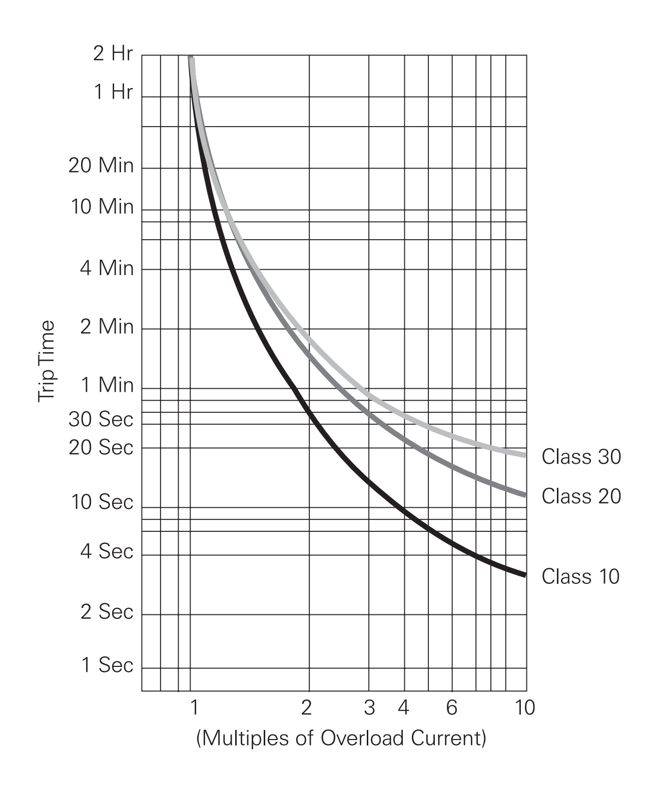
# Motor Starters

The motor starter is the heart of the combination motor control unit. Motor starters consist of a contactor and an overload relay. The contactor portion of a motor starter provides the means to remotely start and stop a motor. The overload relay protects the motor from overload conditions.



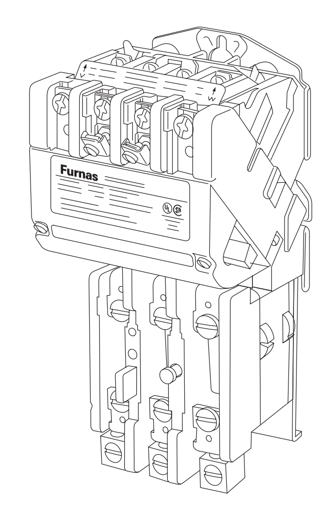
## Overload Relay Trip Classes

Overload relays are rated by a trip class, which defines the length of time it will take for the relay to trip in an overload condition. The most common trip classes are Class 10, Class 20 and Class 30. Class 10, for example, has to trip the motor off line in 10 seconds or less at 600% of the full load amps. This is usually sufficient time for the motor to reach full speed. Many industrial loads, particularly high inertia loads, use Class 20.



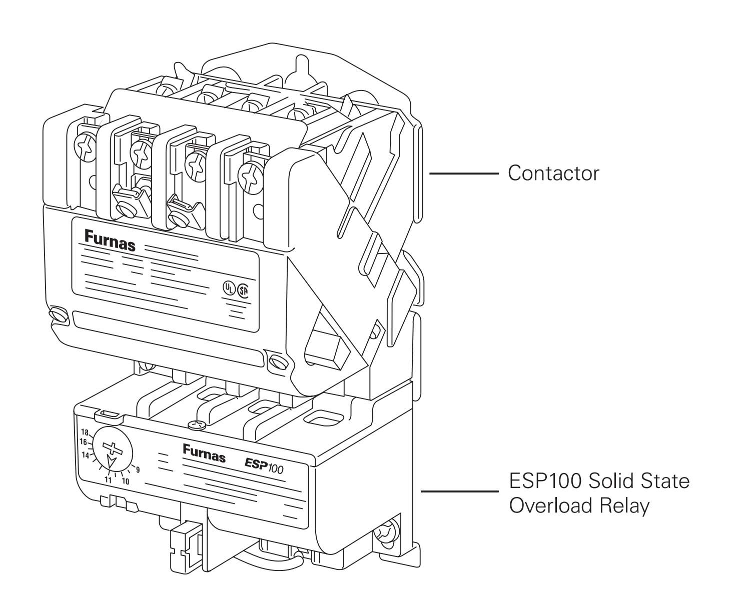

## INNOVA PLUS

INNOVA PLUS™ is one type of starter which can be used in motor control centers. INNOVA PLUS starters are available with a Class 20 melting alloy type overload relay as standard. Class 10 or Class 20 ambient compensated or non-compensated bimetal overload relays are also available.

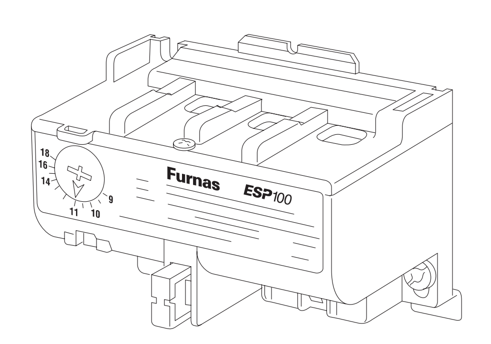


## ESP100

The Furnas ESP100™ starters use the same contactor as the INNOVA PLUS™ starters. The ESP100 starters are supplied with a Class 10, 20, or 30 solid-state overload relay. The ESP100 also protects the motor against phase loss. The ESP100 trips within three seconds of loss of one of the power supply phases.

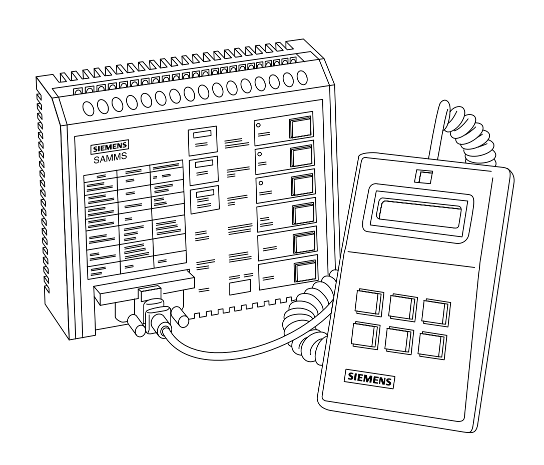



A single ESP100 overload relay replaces at least six size ranges of heaters. Instead of installing heaters the full load amperes (FLA) of the motor is set with a dial. The ESP100 overload relay protects 3Ø motors with FLA of ¼ ampere through 540 amperes. From ¼ ampere to 10 amperes the overload has a 4:1 FLA range; i.e. 2½ - 10 amperes. Above 10 amperes the range is 2:1. The ESP100 overload relay illustrated below, for example, is adjustable from 9 to 18 amperes.



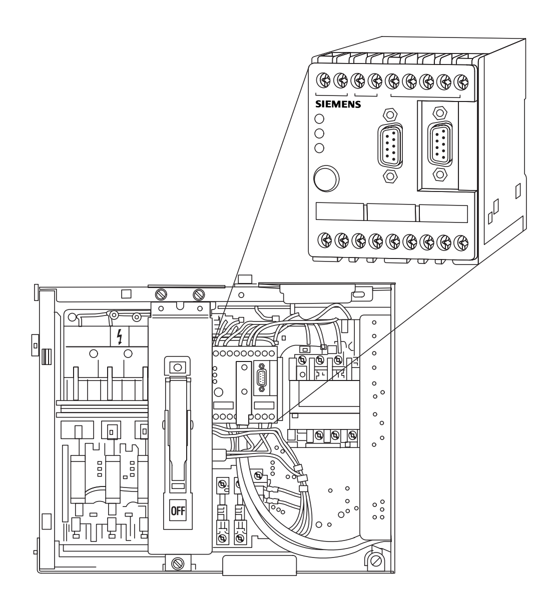
## SAMMS

Siemens contactors can also be configured for use with the Siemens Advanced Motor Master System (SAMMS™). The SAMMS unit is a UL-recognized microprocessor-based motor control and protection device designed specifically for use in motor control centers. SAMMS provides microprocessor-based control and protection for all NEMA-rated low-voltage motors. Full communication options are available with SAMMS.




## SIMOCODE-DP

SIMOCODE-DP is another motor protection and control device. In addition to NEMA class 5, 10, 15, 20, 25, and 30 overload trip characteristics SIMOCODE-DP provides current asymmetry (phase loss, phase imbalance, phase reversal), stalled rotor, over current, under current, and ground fault protection. In addition, inputs to SIMOCODE-DP devices can be used to monitor the status of digital signals typically associated  motor control such as pilot devices and float or pressure switches. Outputs can be used to control contactors, relays, and pilot lights. Although SIMOCODE-DP is desgined to work with PROFIBUS-DP, it will also work independant of a communication network.



## Starter Ratings

Starter contactors are rated according to size and type of load they handle. The International Electrotechnical Commission (IEC) and NEMA rate contactors and motor starters. IEC is associated with equipment sold in many countries including the United States. NEMA is primarily associated with equipment used in North America.

IEC ratings are maximum operational current as specified by the International Electrotechnical Commission. IEC does not specify sizes. The buyer needs to make clear which standards he expects to be met.

NEMA specifies sizes from size 00 to size 9, which cover the horsepower range from 2 HP to 1,600 HP at 460 volts.

| Size of Controller | Horsepower at 460 V / 60 Hz |
|---|---|
| 00 | 2 |
| 0 | 5 |
| 1 | 10 |
| 2 | 25 |
| 3 | 50 |
| 4 | 100 |
| 5 | 200 |
| 6 | 400 |
| 7 | 600 |
| 8 | 900 |
| 9 | 1600 |

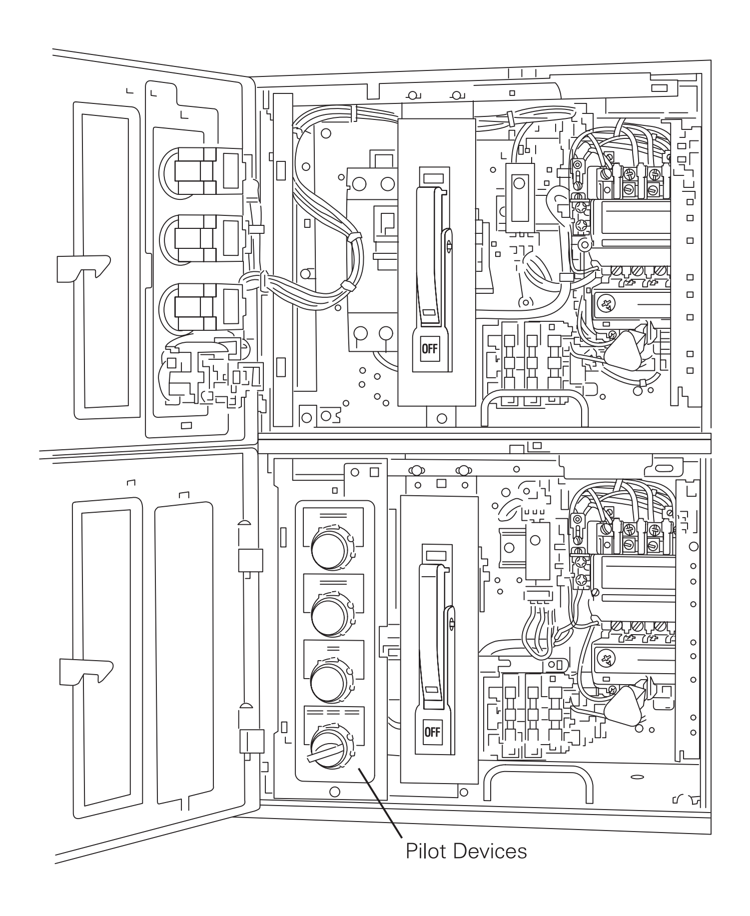
## Types of Starters

Starters can be configured to perform several different tasks. The following types of combination starters can be found in Siemens motor control centers:

FVNR Full Voltage Non-Reversing
FVR Full Voltage Reversing
2S1W Two Speed One Winding Reconnectable Consequent Pole Unit
2S2W Two Speed Two Winding
PW Full Voltage Part Winding
RVAT Reduced Voltage Auto-Transformer (Closed Transition)
3YD Wye Delta (Open or Closed Transition)

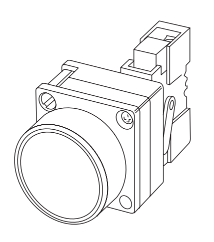
# Pilot Devices

A number of pilot devices can be used on Siemens motor control centers. Pilot devices include pushbuttons, selector switches, and pilot lights.

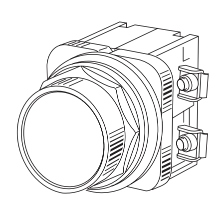


## Pushbuttons

A pushbutton is a control device used to manually open and close a set of contacts. Pushbuttons are available in a flush mount, extended mount, with a mushroom head, illuminated, or non-illuminated. Pushbuttons come with either normally open, normally closed, or a combination contact block.



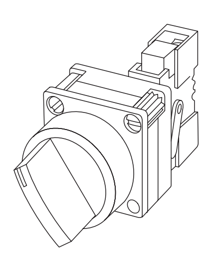
Siemens
22 mm Diameter
Pushbutton



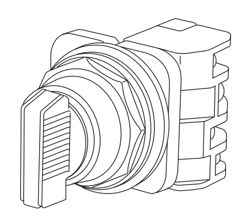
Siemens Furnas Control
30 mm Class 52
Pushbutton

## Selector Switches

Selector switches are also used to manually open and close contacts. Selector switches can be maintained, spring return, or key operated. Selector switches are available in 2-, 3-, and 4-position types.



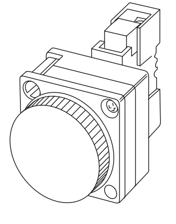
Siemens
22 mm Diameter
Selector Switch



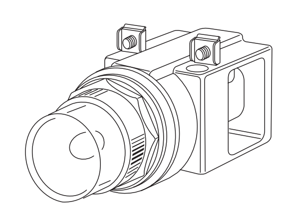
Siemens Furnas Control
30 mm Class 52
Selector Switch

## Pilot Lights

Pilot lights provide visual information of the circuit's operating condition. Pilot lights are normally used for ON/OFF indication, caution, changing conditions, and alarm signaling. Pilot lights come with a color lens, such as red, green, amber, blue, white, or clear.



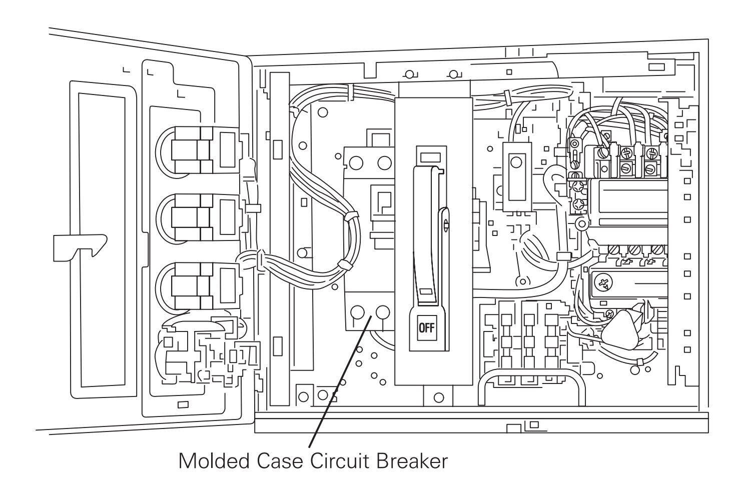
Siemens
22 mm Diameter
Pilot Light



Furnas
30 mm Class 52
Pilot Light

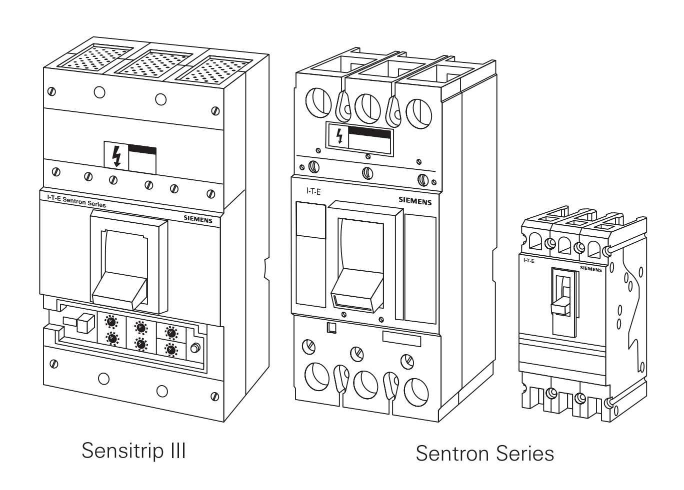
## Circuit Breakers

Circuit breakers are typically used as disconnect devices in combination motor control units. Circuit breakers provide a manual means of energizing and de-energizing a circuit. In addition, circuit breakers provide automatic overcurrent protection of a circuit.




Molded Case Circuit Breaker

Siemens Sentron™ circuit breakers are available with ampere ratings up to 2000 amps. The Sentron series is also available in a digital version, referred to as Sensitrip III. Sensitrip III circuit breakers utilize a microcomputer which makes it possible to customize overcurrent protection which is matched exactly to the loads of an electrical system.



Sensitrip III

Sentron Series

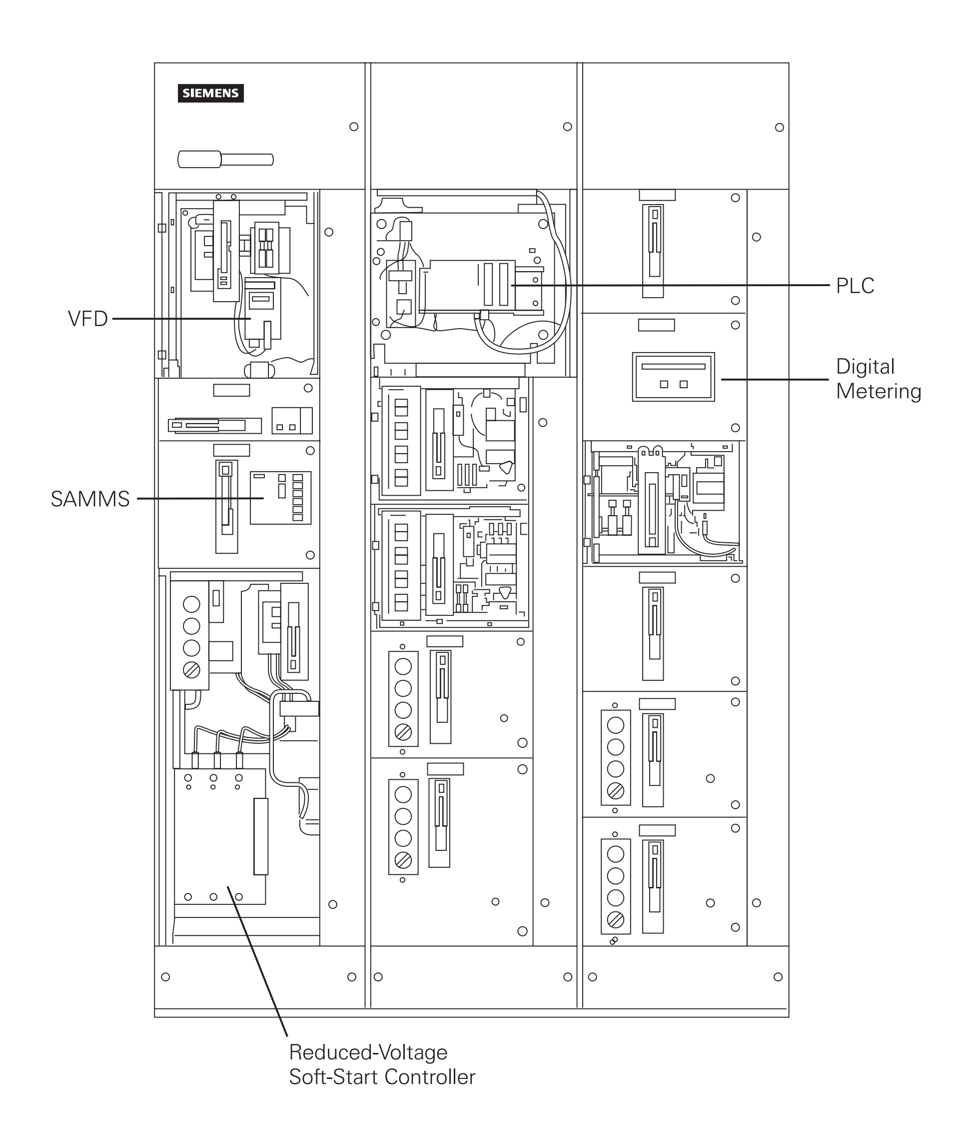
## Circuit Breaker Ratings

There are two types of circuit breakers that are typically used in motor control centers. Thermal-magnetic circuit breakers have both overload and instantaneous trip features. When an overload condition exists, the excess current generates heat, which is detected in the circuit breaker. After a short period of time, depending on the rating of the breaker and the amount of overload, the breaker will trip, disconnecting the load from the voltage source. If a short circuit occurs, the breaker responds instantaneously to the fault current and disconnects the circuit. This type of circuit breaker is used in applications where a motor starter is not used, such as a main disconnect for the MCC or a feeder tap unit. Thermal-magnetic circuit breakers are not used in conjuction with a motor starter.

Instantaneous trip-only circuit breakers are also referred to as magnetic only or Type ETI circuit breakers. Type ETI circuit breakers provide short circuit protection, but they do not provide overload protection. Type ETI circuit breakers are commonly used in combination motor control units where a motor starter, such as the Furnas ESP100, provides overload protection. ETI trip ranges are selected to meet maximum settings per *NEC®* table 430.52 and Article 430.52(C)(3). The instantaneous trip-only circuit breaker is factory set at the LOW position. In accordance with the *National Electical Code®*, the setting on an instantaneous trip circuit breaker may be increased over 800%, but cannot be increased over 1300% of full load amps for a NEMA B motor.

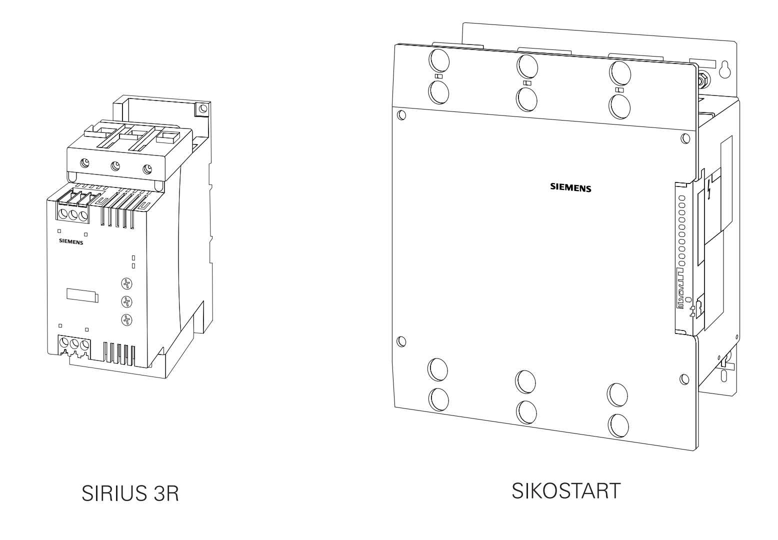
# OtherTypes of Units in MCCs

Siemens motor control centers may include solid-state motor control devices, such as reduced-voltage soft-start controllers, variable frequency drives (VFD), and programmable logic controllers (PLCs). In addition, power meters can be used to measure real-time RMS values of phase currents, phase and line voltages, power usage, power factor, KW, frequency, and peak demand.



**Reduced-Voltage Soft-Start Controllers**

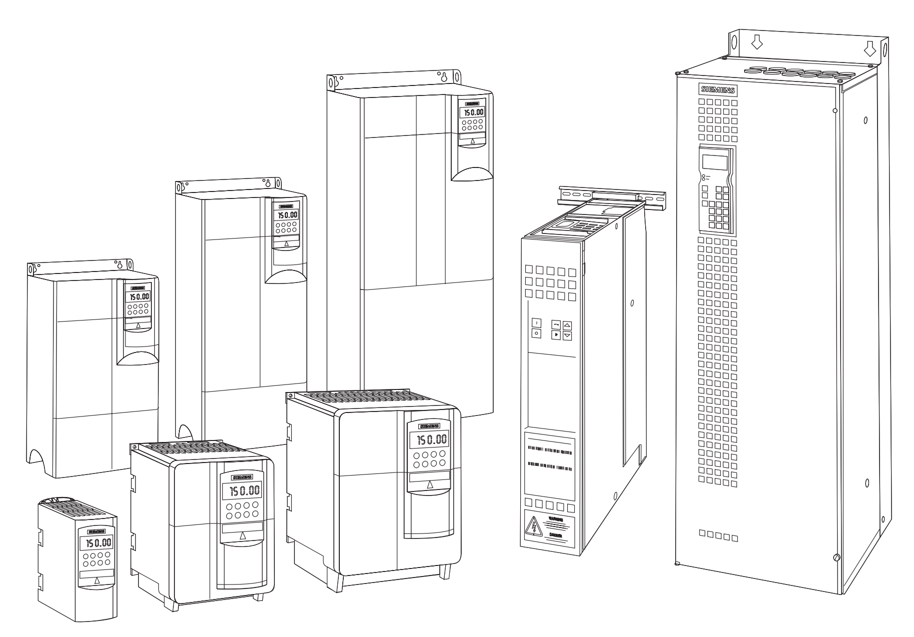
Reduced-voltage soft-start motor-starting controls, such as the SIRIUS or SIKOSTART reduced-voltage controllers, provides a smooth start while minimizing the high starting current and torque associated with across-the-line motor starting. SIRIUS controllers are available in models that will handle up to 60 HP at 460 volts and 75 HP at 575 volts. SIKOSTART are available in models that will handle up to 800 HP at 460 volts and1000 HP at 575 volts.



SIRIUS 3R SIKOSTART

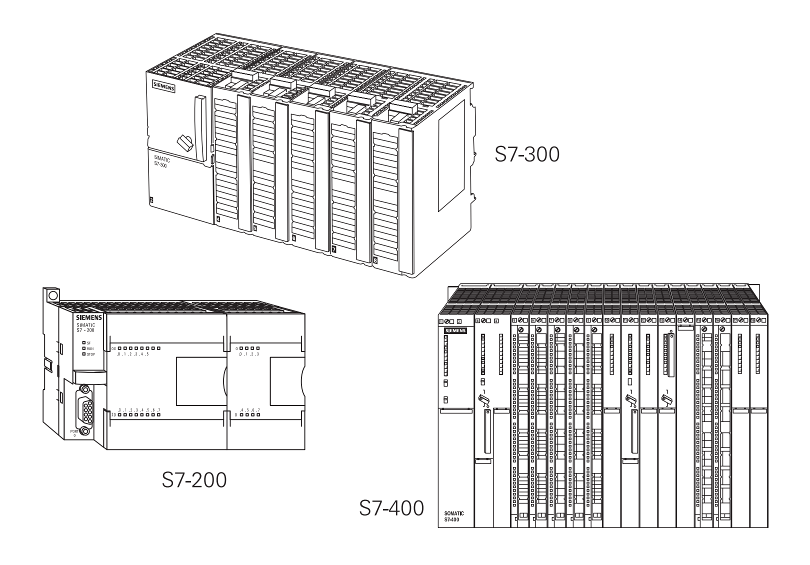
**Variable Frequency Drives**

Variable frequency drives are also referred to as AC drives. A typical AC drive receives 480 VAC, three-phase, 60 Hz input power which is used to start and stop a motor and control the operation of the motor throughout the speed range. A few features of Siemens AC drives include serial communication, DC injection braking, flux current control, vector control, pulsed resistor braking, and drive and motor protection. Siemens AC drives up to 250 HP at 480 VAC are available in MCCs.



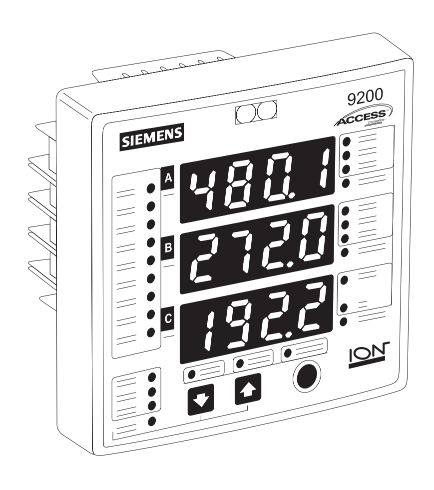
## PLCs

PLCs consist of input modules or points, a central processing unit (CPU), and output modules or points. An input to a PLC may come from a variety of digital or analog signals from various field devices. The PLC converts the input signal into a logic signal that can be used by the CPU. Output modules convert control signals from the CPU into a digital or analog signal that can be used to control various field devices, such as a motor starter, an AC drive, or a reduced- voltage soft-start starter.



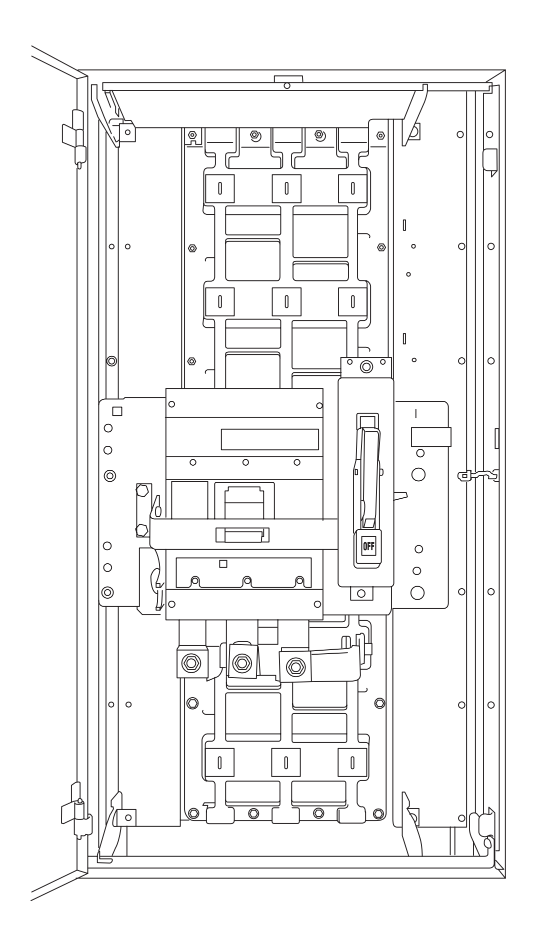

## Digital Metering

Digital metering provides a highly accurate measure of current and power in industrial applications. Meters, such as the Siemens 9200, can replace multiple analog meters and have communication capabilities through the Siemens ACCESS™ system.



## Other Units

There are other units that end up in MCCs such as relay panels, panelboards, and feeder-tap units. A feeder-tap unit, such as the one shown in the following illustration, is typically used to supply power to non-motor loads located downstream of the motor control center.




## UL Marks

A motor control center has two UL marks. One is for the structure and bus, and one for each control unit. Some MCCs may contain special sections or units that have not been UL tested and therefore may not be able to carry the UL mark. Some municipalities may not allow devices that do not carry the UL mark.

## Review 4

1. Class ____________ provides the highest level of overload protection.

2. The ESP100 trips within ____________ seconds of loss of one of the power-supply phases.

3. A size 5 controller is rated for ____________ HP.

4. Which of the following devices can be used in a Siemens motor control center?

   a. reduced-voltage starter
   b. variable frequency drive
   c. PLC
   d. SAMMS
   e. digital metering
   f. all of the above

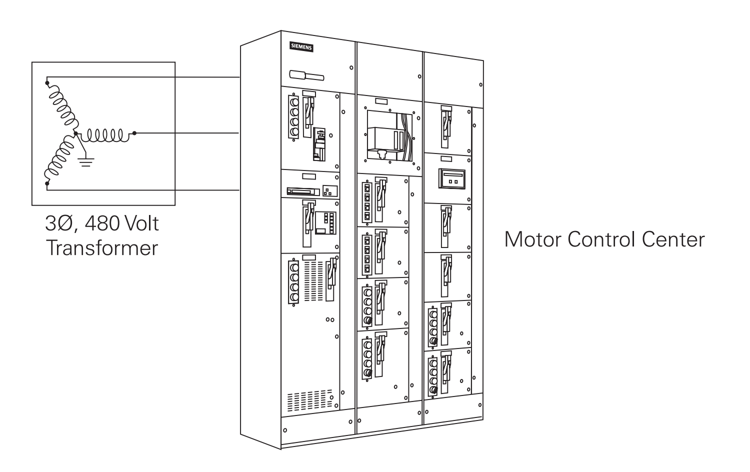
5. ____________ and ____________ are Siemens trade names for a reduced-voltage soft-start controller.

# MCC Ratings

In addition to the various ratings of individual components used in motor control centers, the overall ratings of the motor control center must also be considered.

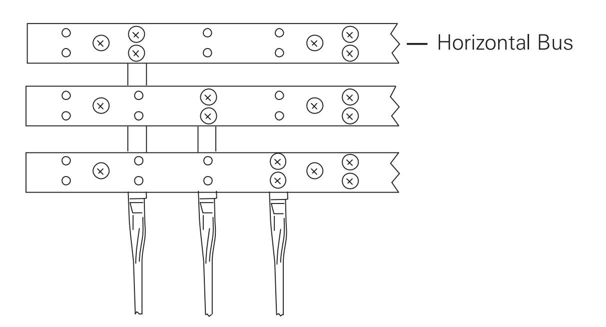
**Voltage Rating**

Motor control centers are rated for 600 volts. This is the maximum voltage that can be applied to a motor control center. A motor control center can be connected to a lower voltage. A motor control center, for example, might be connected to a three-phase, 480 VAC power supply.



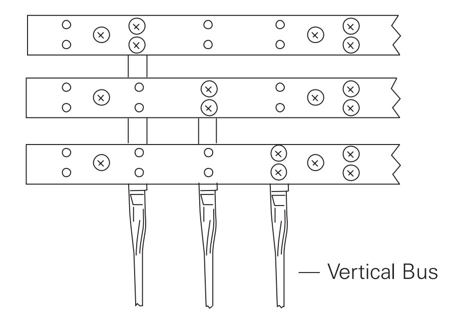

**Horizontal Bus Current Rating**

The horizontal bus on Siemens motor control centers are made of tin or optional silver plated copper. They are available with 600A, 800A, 1200A, 1600A, and 2000A current ratings.



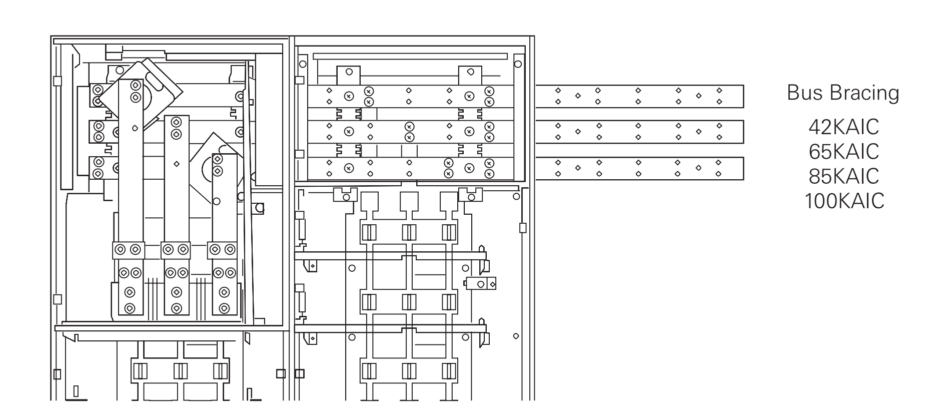
**Vertical Bus**

The vertical bus on the TIASTAR motor control centers are available with 300A and 600A ratings.




**Bus Bracing**

Motor control centers must be capable of withstanding the largest potential short-circuit current which can occur in the selected application. The amount of short-circuit current available depends on the amount of power available to a facility. Short-circuit current can be thousands of times higher than normal current. Bus bars must be braced to withstand this potential current. Siemens bus bars are braced for 42,000 AIC (ampere interrupting capacity) with optional bracing available to 100,000 AIC.

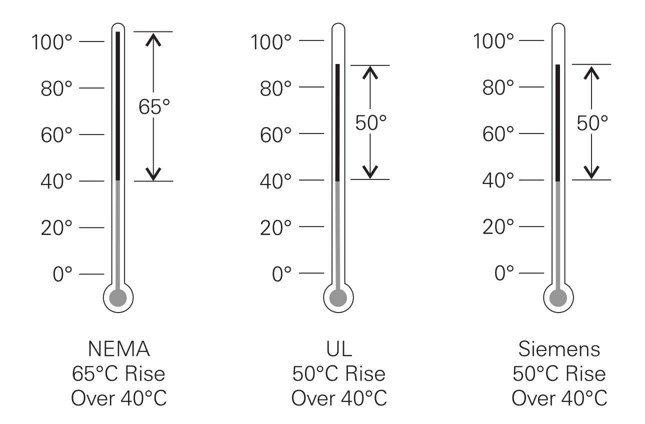


## Temperature Rise

The bus bars are the major current carrying component of the motor control center. Before a motor control center is operated, bus bars are at the temperature of the surrounding air. This is known as ambient temperature. Temperature rises in the motor control center bus bars during operation. The combination of ambient temperature and allowed temperature rise equals the maximum temperature of the bus bars.

NEMA and UL both have standards concerning the maximum temperature rise of bus bars used in motor control centers. NEMA limits temperature rise to 65°C based on an ambient temperature of 40°C (104°F), for a maximum operating temperature of 105°C. UL limits temperature rise to 50°C based on an ambient temperature of 40°C (104°F), for a maximum operating temperature of 90°C. Electrical equipment bearing a UL mark must meet or exceed this standard.

Siemens motor control centers meet or exceed NEMA and UL standards. Bus bars in Siemens motor control centers are tested with a maximum temperature rise of 50°C over 40°C (104°F) ambient.



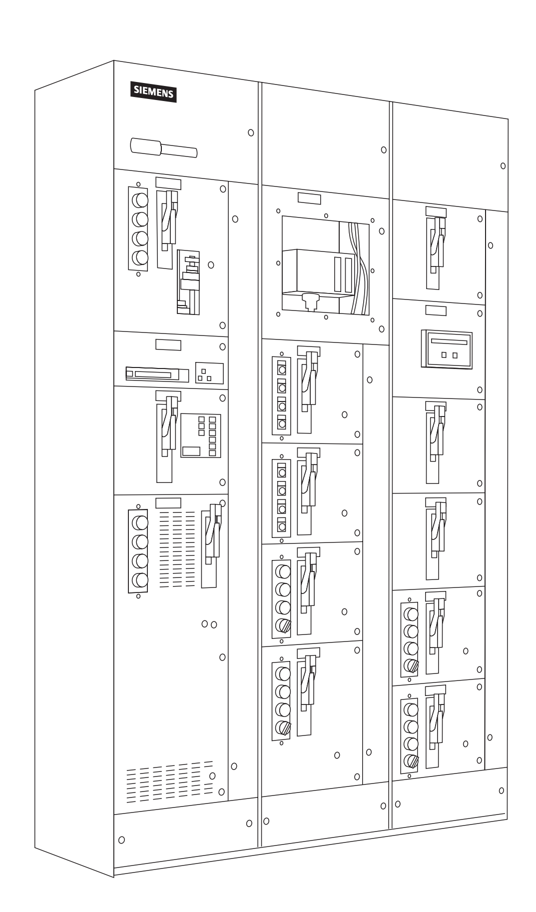
# Enclosures

NEMA defines an enclosure as *a surrounding case constructed to provide a degree of protection to personnel against incidental contact with the enclosed equipment and to provide a degree of protection to the enclosed equipment against specified environmental conditions* (NEMA Standard 250 - section 2, definitions).

The following brief descriptions cover enclosures available for Siemens motor control centers.

**Type 1 Enclosure**

Type 1 enclosures are intended for indoor use primarily to provide protection against limited amounts of falling dirt and contact with the enclosed equipment in locations where unusual service conditions do not exist.



**Type 1 Gasket Front**

Type 1 gasketed front, general purpose, indoor enclosure has the same use as Type 1 except the front of the enclosure is gasketed. In addition the following parts are gasketed:

Unit separator angles
Right-hand side of front of units
Bottom horizontal cross ties
Lip on top plate
Pilot-device panel
Handle mechanism
Bottom horizontal wireway cover plate
Side holes are plugged

**Type 2, Drip-Proof**

Type 2, drip-proof is an indoor enclosure intended to protect equipment from falling noncorrosive liquids and dirt. The enclosure prevents the entrance of dripping liquid at a higher level than the lowest live part within the enclosure. This design is a Type 1 gasketed front, or Type 12, with a drip shield mounted on top of the enclosure.

**Type 12 Enclosure**

Type 12 enclosures are intended for indoor use primarily to provide a degree of protection against circulating dust, falling dirt, and dripping noncorrosive liquids. They are not intended to provide protection against conditions such as internal condensation.

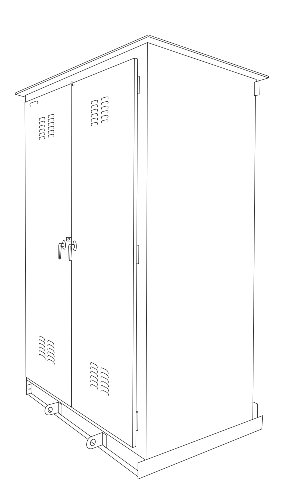
The Type 12 will provide a greater degree of protection than a Type 1 gasketed enclosure. The following additional parts are gasketed:

Hinged side of doors
Top plates
Wireway end-covers
Rear plates

There is no gap between sections, allowing for much greater dust resistance. In addition, interconnection holes in the side sheet assemblies are sealed. Bottom plates are included.

**Type 3R Enclosure**

Type 3R enclosures are intended for outdoor use primarily to provide a degree of protection against falling rain and sleet and protection from contact with the enclosed equipment. They are not dust, snow, or sleet (ice) proof. They will prevent entrance of rain at a level higher than the lowest live part. The enclosure has provisions for locking and drainage.



The enclosure entirely surrounds the motor control center for outdoor operation. The Type 3R enclosure is designed to accommodate bottom cable entry and exit only. The 3R enclosure is not a walk-in type design.

**NEMA and IEC**

The International Electrotechnical Commission (IEC) is another organization that defines the degree of protection provided by enclosures. NEMA is primarily associated with equipment used in North America. IEC is associated with equipment sold in many countries including the United States.

The IEC designation consists of the letters IP followed by two numbers. The first number indicates the degree of protection provided by the enclosure with respect to persons and solid objects entering the enclosure. The second number indicates the degree of protection against the ingress of water. The following chart provides an equivalent conversion between NEMA and IEC designations.

| NEMA | IEC |
|---|---|
| 1 | IP10 |
| 2 | IP11 |
| 3R | IP14 |
| 12 | IP52 |

# Classification and Types of Wiring

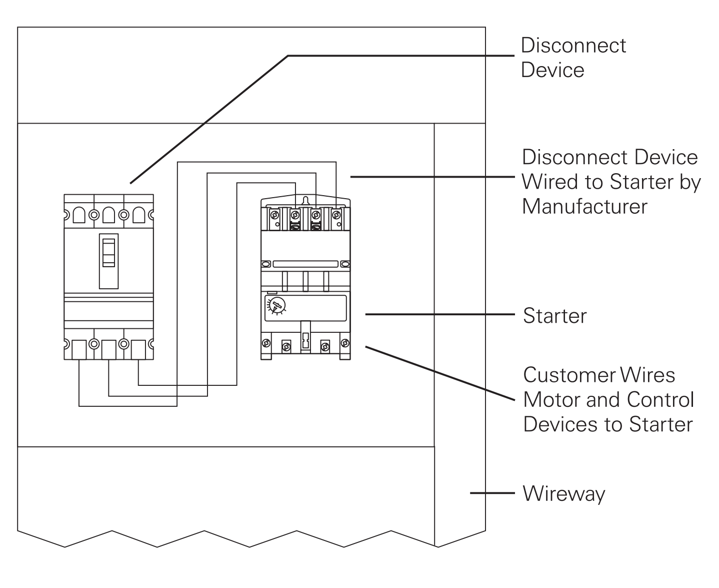
NEMA has established two classification standards (Class I and Class II) and three types of wiring (A, B, and C) used in the construction of motor control centers. These are specified by the customer.

**Class I**

Class I consists of a grouping of combination motor control units in which each starter and motor operates independently of the other starters. The factory connects the combination motor control units to the vertical bus but does not provide interconnecting wiring between combination motor control units, different vertical units, or remotely connected devices. Diagrams of the individual units only are supplied.

**Class I, Type A Wiring**

Type A wiring is only available on Class I motor control centers. The motor control center manufacturer connects the combination motor control unit to the vertical bus via the stabs on the back of the unit. Power is applied to the circuit breaker from the vertical bus. The circuit breaker is factory wired to the motor starter. The customer connects the motor leads and control wiring to the motor starter. There is no interconnecting wiring between combination motor control units.

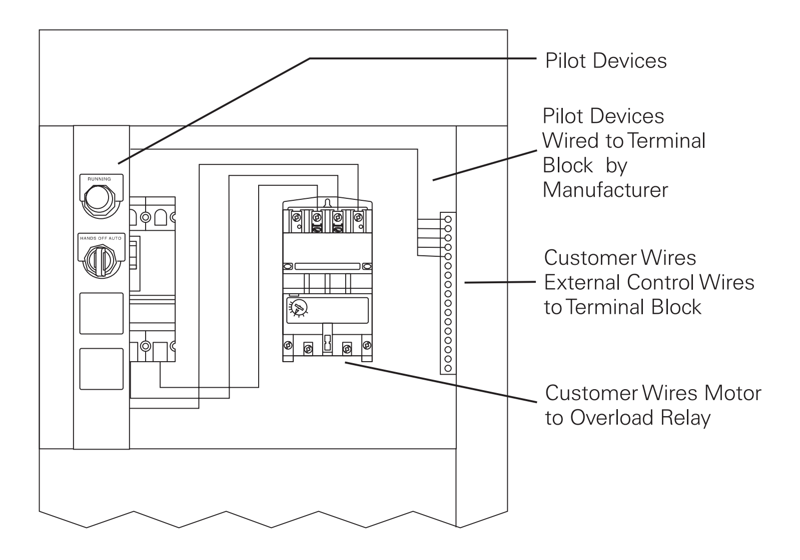



Vertical Section

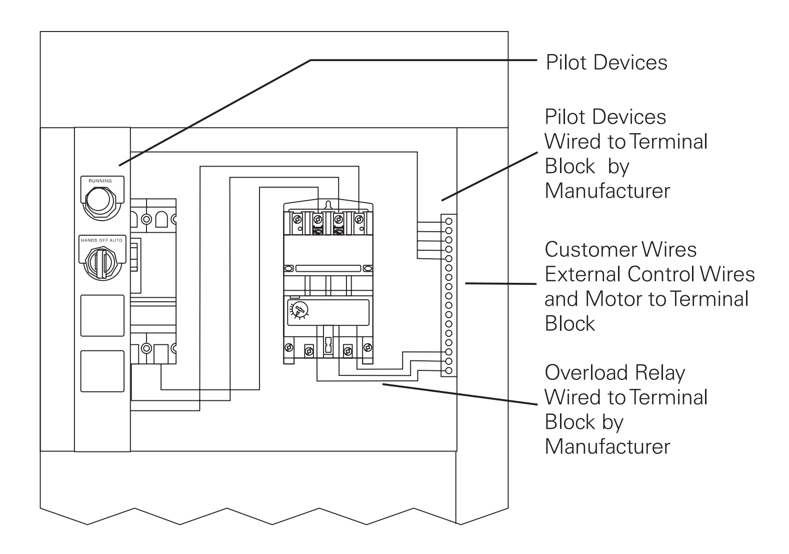
**Class I, Type B Wiring**

Typically pilot devices, such as indicator lights, pushbuttons, and selector switches, are used with Class I, Type B wiring. Type B wiring is divided into two designations: B-d (-d for connection of load wires directly on starter or contactor terminals) and B-t (-t for connection of load wires to unit mounted load terminal blocks).

When Type B-d wiring is specified, terminal blocks are furnished near the wireway for control circuit connections. Motor leads are connected directly to the overload relay terminals.

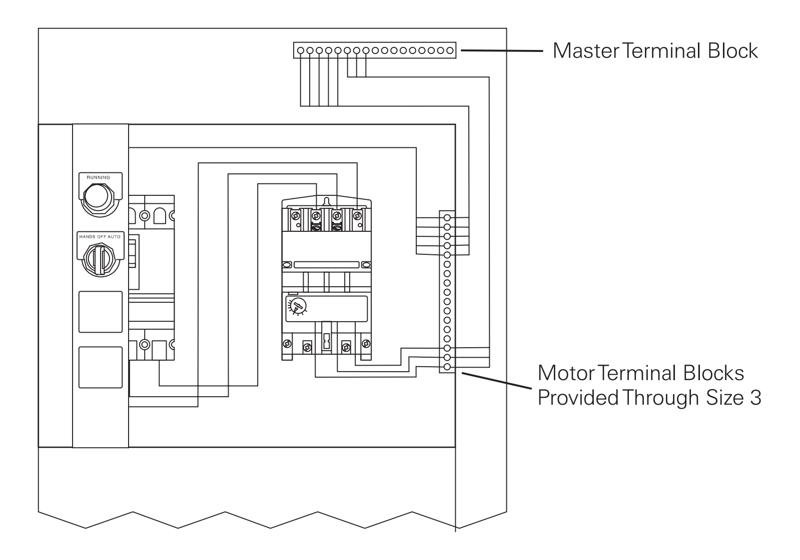



When Type B-t wiring is specified, terminal blocks are furnished near the wireway for control circuit connections and for motor starter leads. Type B-t wiring can be used on starters up to size 3.



## Class I, Type C Wiring

With Type C wiring, a master terminal block is provided in either the top or bottom horizontal wiring gutter. The manufacturer of the motor control center brings the control wires from each control unit to the master terminal block. The installer is then able to make his wiring connections at the master terminal block. With Type C wiring, load wiring for combination motor control units smaller than size 3 (50 HP) are connected to the master terminal block. Load wiring for combination motor control units larger than size 3 are connected directly to unit device terminals..

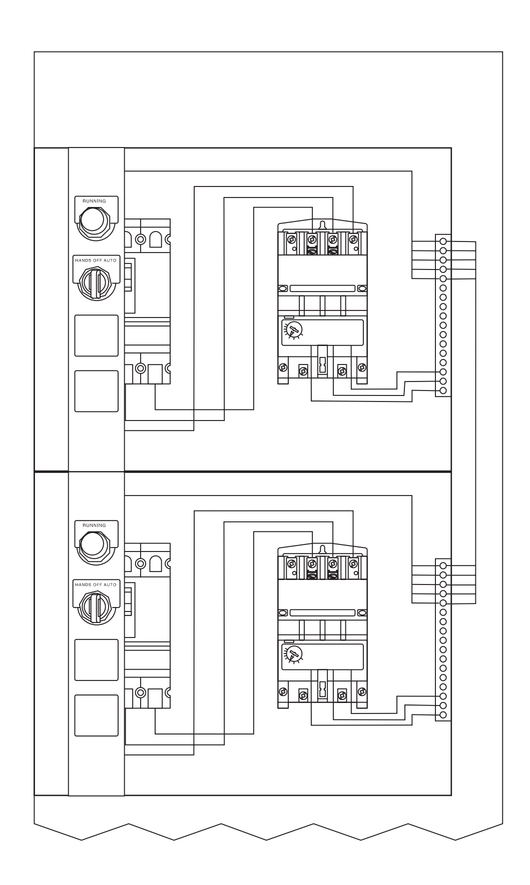


**Class II**

Class II consists of a grouping of combination motor control units with interwiring and interlocking between the starters to form a complete control system. Wiring diagrams, including the interwiring, is furnished. Class II is generally specified when a group of motors requires sequencing, interlocking, or interconnecting.

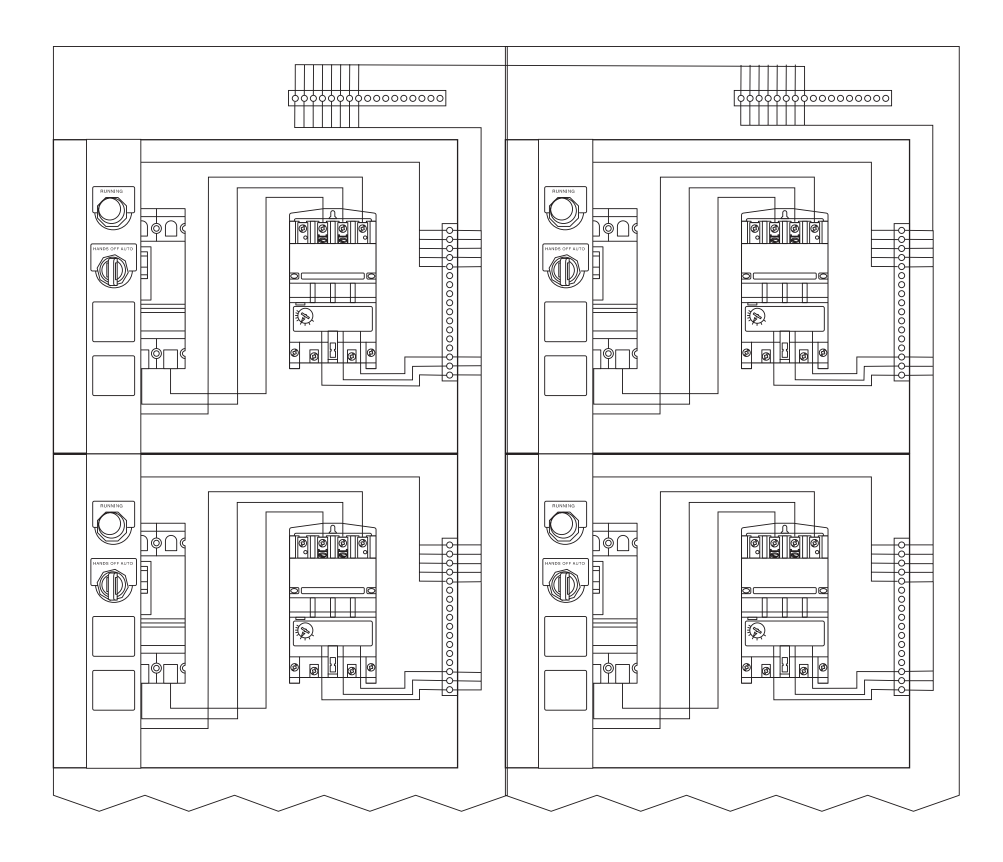
**Class II, Type B**

Class II, Type B wiring is similar to Class I, Type B wiring. Terminal blocks are furnished near the wireway. In addition, Class II, Type B wiring includes interconnecting wiring between motor starters.



## Class II, Type C

Class II, Type C wiring is similar to Class I, Type C wiring. In addition, Class II, Type C wiring includes interconnecting wiring between motor starters and vertical sections.



## Reference Chart

The following chart provides a handy reference when determining the class and type of wiring used in motor control centers.

| Description | Class I Types | | | | Class II Types | | |
|---|---|---|---|---|---|---|---|
| | A | B-d | B-t | C | B-d | B-t | C |
| Terminals Required | | | | | | | |
| For all Control Connections | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| For Starter Load Connections Sizes 1 through 3 ① | | | ✓ | ✓ | | ✓ | ✓ |
| Terminals Mounted | | | | | | | |
| On Control Unit | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| In Master Terminal Compartment ② | | | | ✓ | | | ✓ |
| Interwiring | | | | | | | |
| Between Units in the same MCC | | | | | ✓ | ✓ | ✓ |
| Diagram | | | | | | | |
| Connection for each Starter or Control Unit | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Elementary and Interconnection of Complete MCC | | | | | ✓ | ✓ | ✓ |
| Other Drawings | | | | | | | |
| Overall Dimensions of MCC | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Location of Terminals in Master Terminal Compartment | | | | | | ✓ | ✓③ |

① No load terminals furnished for starters sizes 3½ through 6, main or branch circuit breaker or fusible switches, distribution transformers or lighting panelboards.

② Located at top or bottom of each section and wired to the various parts.

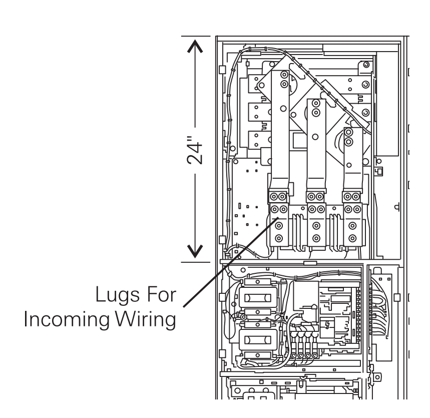
③ Included on motor control center interconnection diagram.

# Cable Entry

There are several ways incoming power can be terminated in a motor control center. Cable can be routed directly to the incoming power lugs, to main breakers or disconnects, or to a terminal block in a vertical section. In addition, incoming power cables can enter and exit the motor control center from the top or bottom depending on the application.

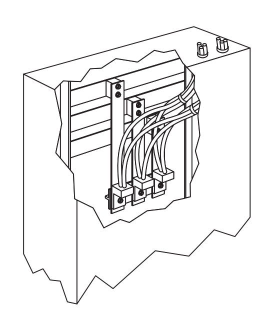
**Main Lugs**

When using main lugs the amount of vertical space required varies with the amperage rating. When the main lugs are located on the top, as in the following illustration, the vertical space is taken at the top. A motor control center can also have the lugs located at the bottom of the MCC. In the following illustration, for example, main lugs rated for 600 amps are located on the top of the MCC. In this example 24" of vertical space is required.



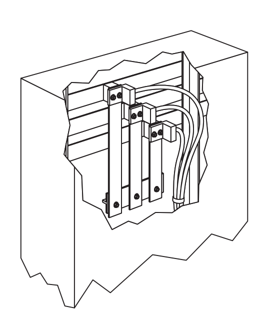
**Main Lugs on Top, Top Entry**

In the arrangement illustrated below incoming power cables enter through the top of a vertical section and are connected to main lugs.



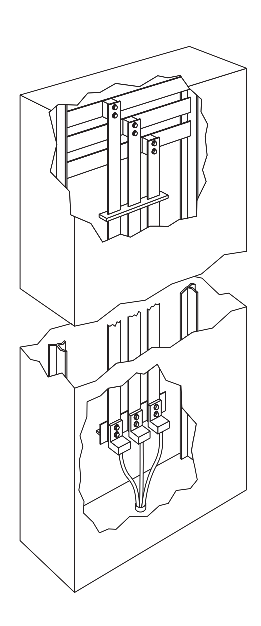
**Main Lugs on Top, Bottom Entry**

Incoming cables can also enter from the bottom and connect to main lugs located in the top section.



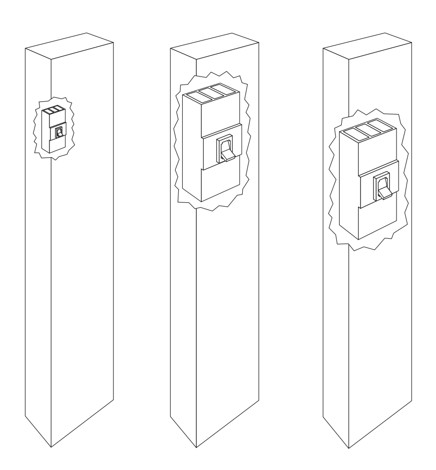
**Main Lugs on Bottom, Bottom Cable Entry**

Lugs can also be supplied on the bottom of the vertical bus for bottom cable entry.

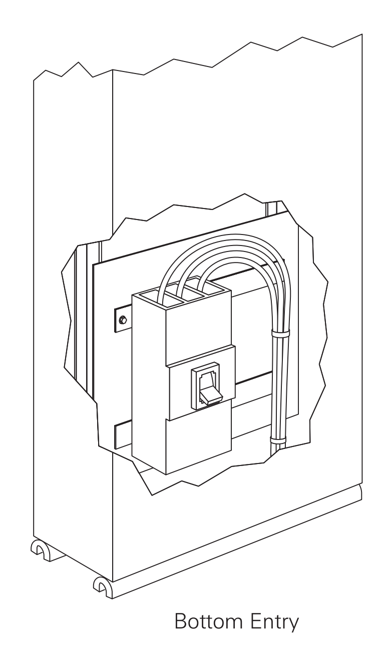


## Disconnect Device

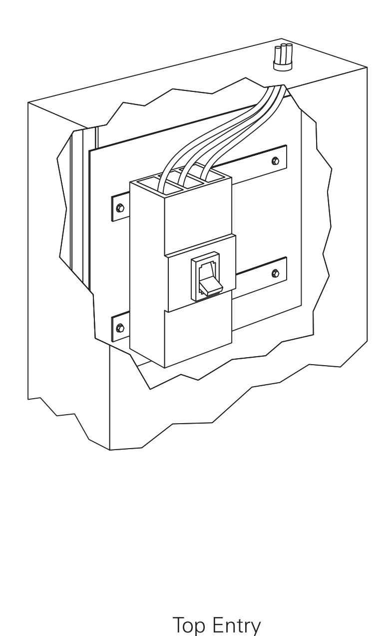
When a main disconnect device, such as a circuit breaker or fusible disconnect, is used, the disconnect is mounted in its own unit. The amount of space required depends on the disconnect used. The space can vary from 12" to 72".



In the following illustration a main circuit breaker is used. Cable entry can be from the top or bottom of the vertical section.



Bottom Entry



Top Entry

## Review 5

1. The maximum current rating for a horizontal bus on Siemens motor control center is ____________ amps.

2. The maximum bus bracing available for a Siemens motor control center is ____________ AIC.

3. The IEC equivalent of a NEMA Type 3R enclosure is ____________ .

4. Identify the following types of Class I wiring:

   a. ____________

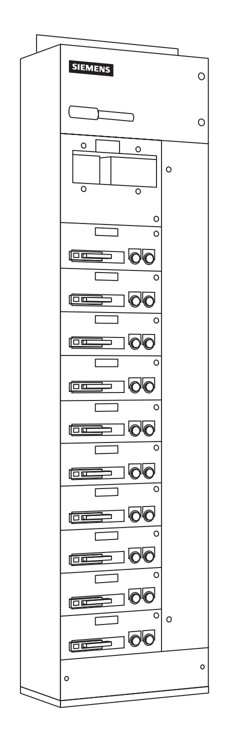
   b. ____________

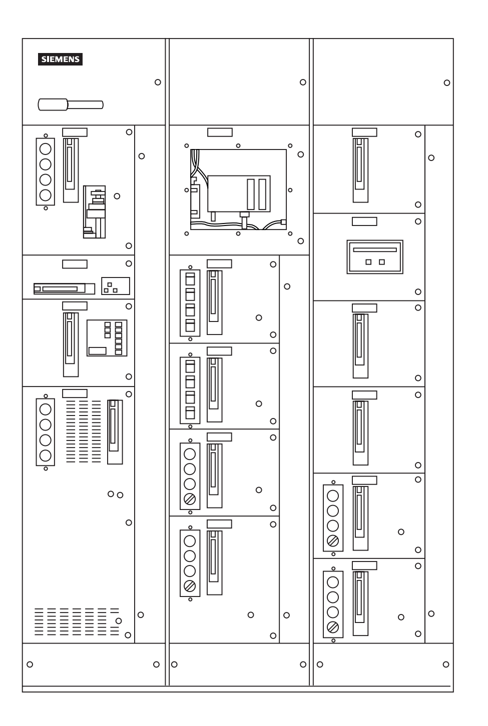
   c. ____________

   d. ____________

# TIASTAR

TIASTAR™ is trade name of the motor control centers that Siemens manufactures. Several mechanisms and features have been designed into TIASTAR. Many of these features will be discussed in this section.

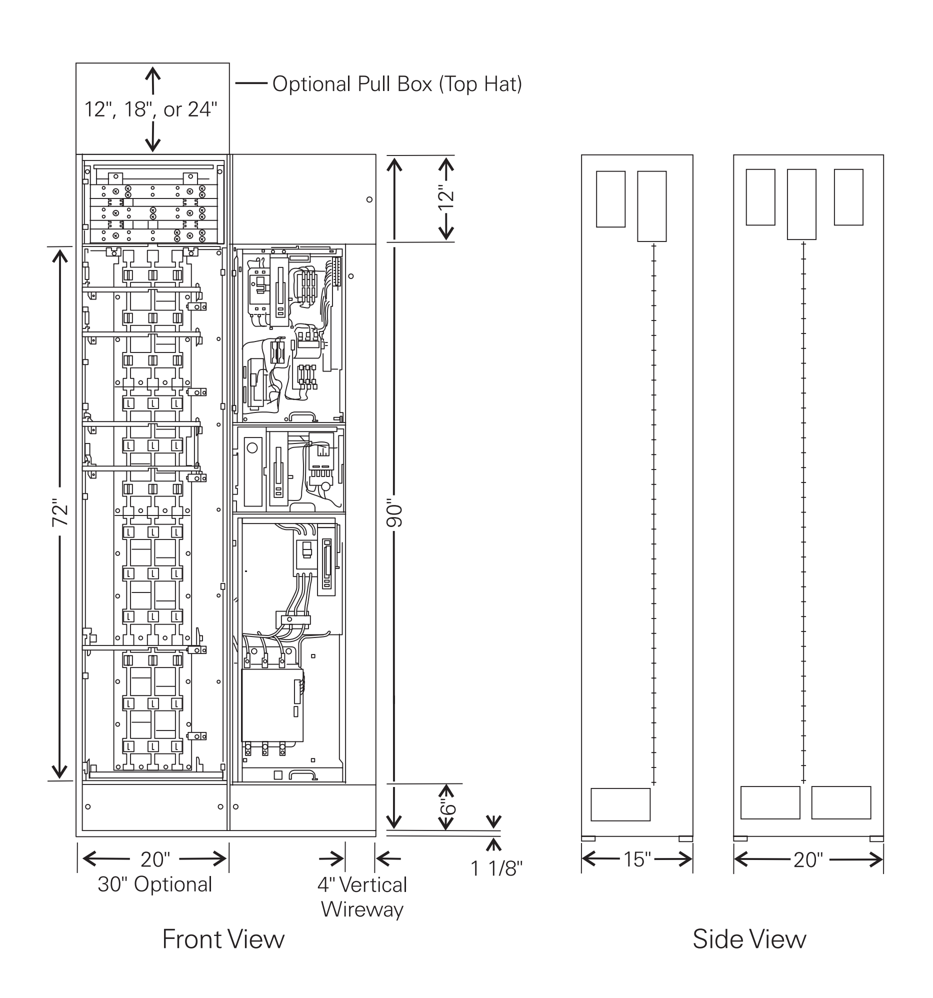


## Dimensions

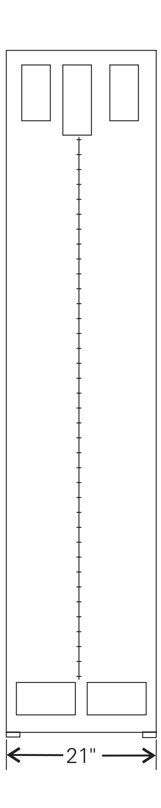
The nominal height of TIASTAR is 90″ high. The overall height is 91 1/8″ including a standard 1 1/8″ base channel. There are 72″ of vertical space available for combination motor control units, with 12″ at the top and 6″ at the bottom for wiring. The horizontal power bus is located in the 12″ of top space making it easier to service. Each vertical unit will hold up to six 12″ units (6 x 12 = 72). An optional pull box (top hat) can be supplied when extra wire-bending space is required. Pull boxes can be 12″, 18″, or 24″ high.

Vertical structures are 20″ wide. A 30″ wide unit is available for special units, such as large AC drives or transformers that require more space. The vertical wireway is 4″ wide on 20″ wide sections. An optional 8″-wide wireway is available on 20″ wide sections. Vertical units can be 15″ or 20″ deep.

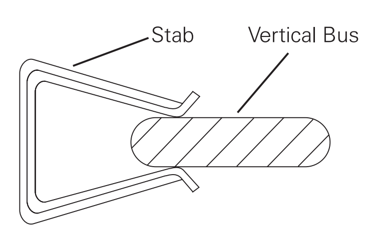


## Back-to-Back Mounting

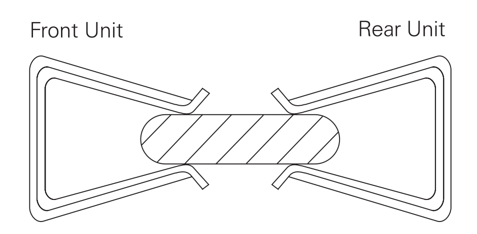
A feature of TIASTAR motor control centers is the ability to mount combination motor control units back to back. This permits mounting 12 combination motor control units in 72″ of vertical space. TIASTAR vertical units designed for back-to-back mounting are 21″ deep.




Back-to-back combination motor control units use the same stab-on connection as front mounted units.




Front Mounted Unit Only



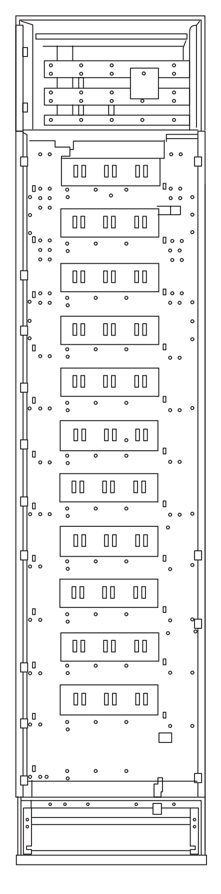

Back-to-Back Mounted Units

## Basic Construction

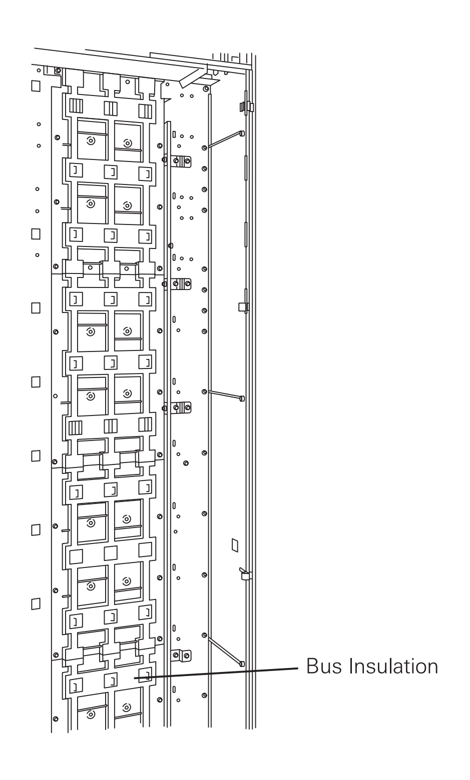
TIASTAR motor control centers offer two vertical bus designs. Front only structures with 42K or 65K bus bracing are supplied with an insulated vertical bus design standard. The vertical bus bars are not physically isolated phase-to-phase.

An optional isolated and insulated vertical bus assembly is available for front only 42K and 65K bus bracing. The isolated and insulated vertical bus design is standard for 100K bus bracing and all back-to-back structures.

Combination motor control units can be interchanged and are easily rearranged on either bus assembly. The unit support brackets can be repositioned to accommodate various size units.



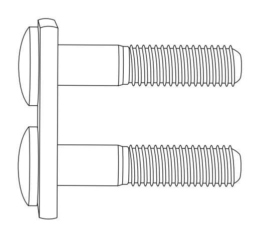
Standard Insulated Vertical Bus



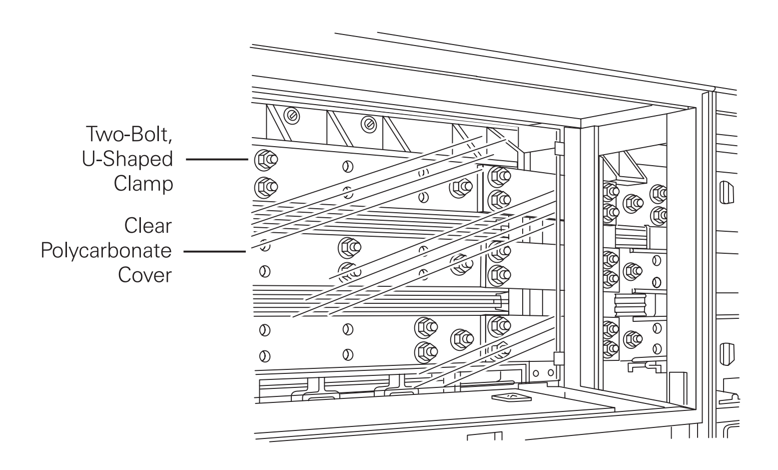

Optional Isolated and Insulated Vertical Bus

## Horizontal Bus

The horizontal bus is connected to the vertical bus with a two-bolt, U-shaped clamp utilizing spring washers to maintain torque. This allows the bolts to be tightened from the front.

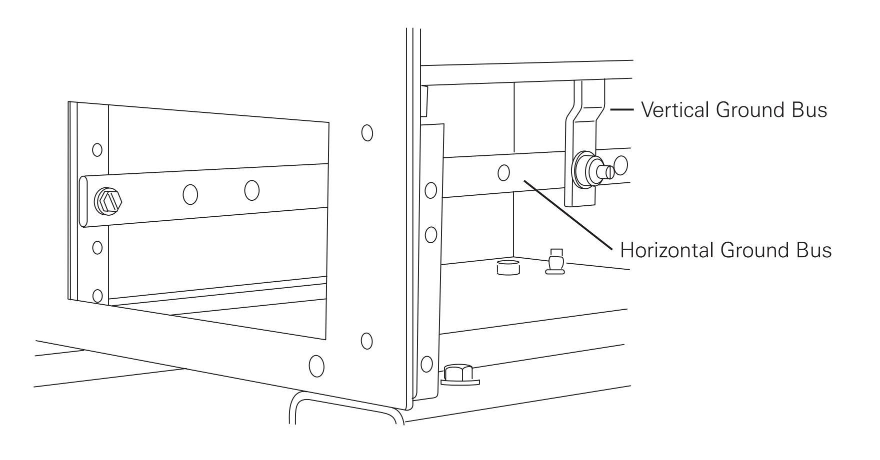


Horizontal bus bars are shielded by a clear polycarbonate cover for safety and easy visibility for inspection.



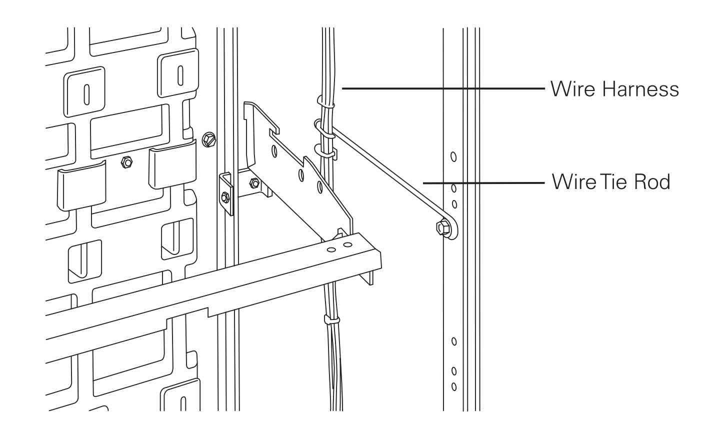

## Ground Bus

A horizontal ground bus is mounted in the bottom 6” of space. The horizontal ground bus is standard. An optional vertical ground bus can be connected to the horizontal bus. When a combination motor control unit is instered into the MCC the vertical ground bus is the first item engaged. Likewise, when the unit is removed the vertical ground bus is the last thing to be disengaged.



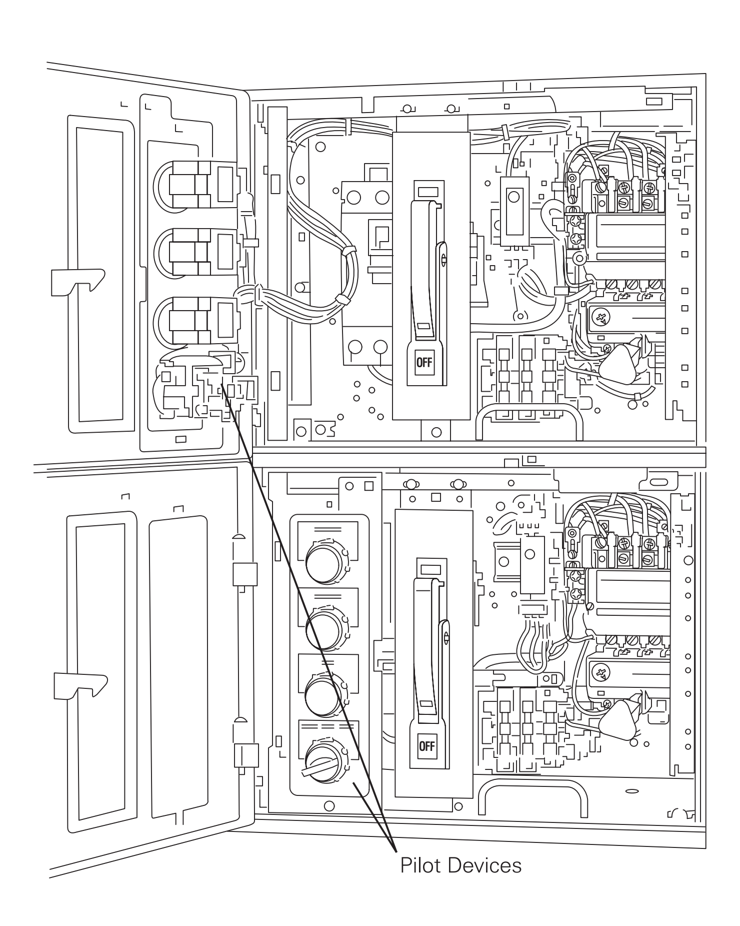
**Wire Tie Rods**

Round wire tie rods are located in each vertical wireway to hold wire harnesses in place.



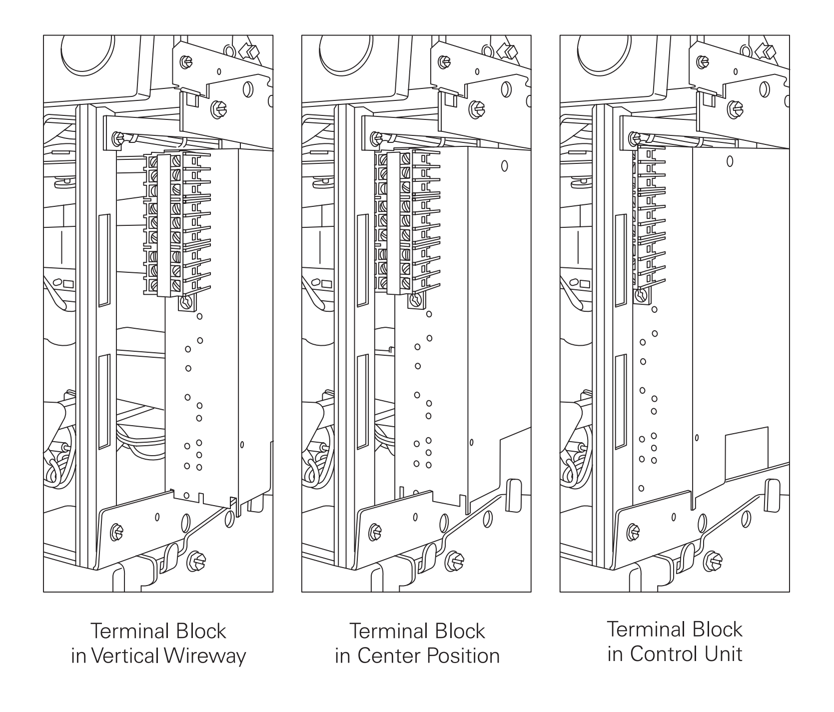

**Pilot Devices**

Pilot devices are mounted on a panel which latches onto the unit door with a simple tab-and-notch mechanism. The pilot-device panel can be removed from the door and attached to the combination motor control unit for service or unit removal. There is room for four 30mm pilot devices on the panel.



## Terminal Blocks

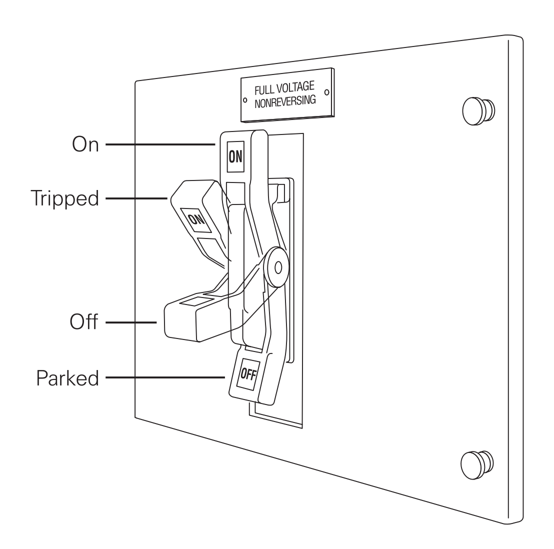
Terminal blocks are supplied with Type B and C wiring. The terminal blocks are mounted up front on a swing-out side panel. The panel is notched so that the terminal block can be placed inside the unit, in a center position, or in the vertical wireway. This secures the terminals inside the unit when access is not required, or allows access from the vertical wireway. Pull-apart terminals are available as an option.



Terminal Block in Vertical Wireway | Terminal Block in Center Position | Terminal Block in Control Unit

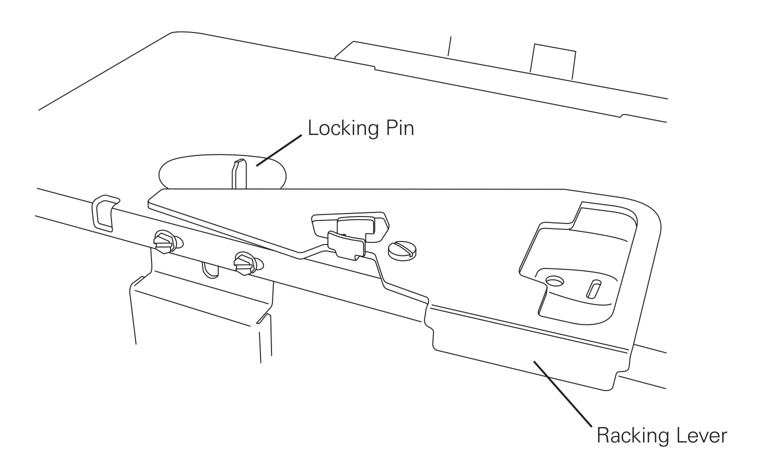
## Operating Handle

The disconnect operating handle has four positions. When placed in the "PARK" position the unit door can be opened without the handle interfering. The "TRIPPED" position is clearly indicated.



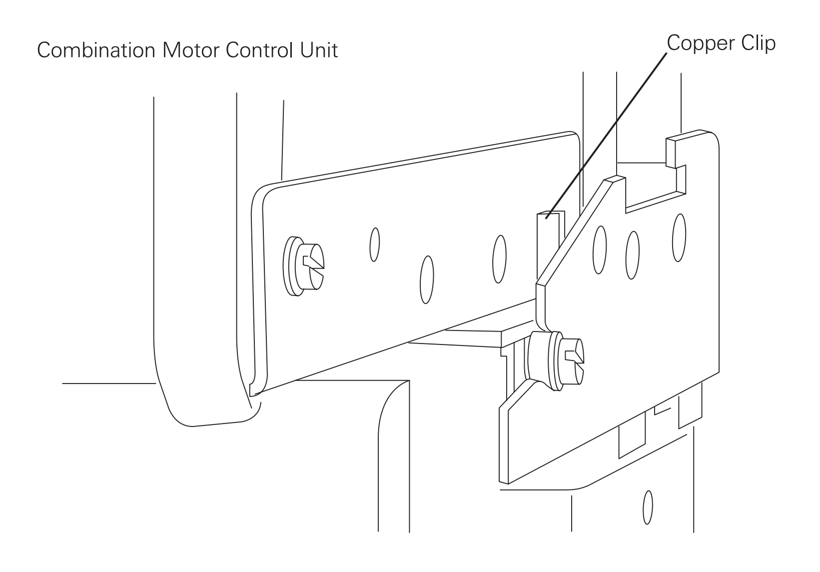
## Racking Lever

A racking lever located on each combination motor control unit is used to remove or install the unit. When the operator handle is in the "ON" position, a locking pin blocks the racking lever closed. When the operator handle is switched to the "OFF" position, the locking pin disengages the racking lever. The combination motor control unit can be pulled to a test position. The operator handle is placed in "PARK" to completely remove the combination motor control unit. The unit is designed so that it cannot be inserted or removed with the operator handle in the "ON" position. In the test position the unit can be padlocked in place.



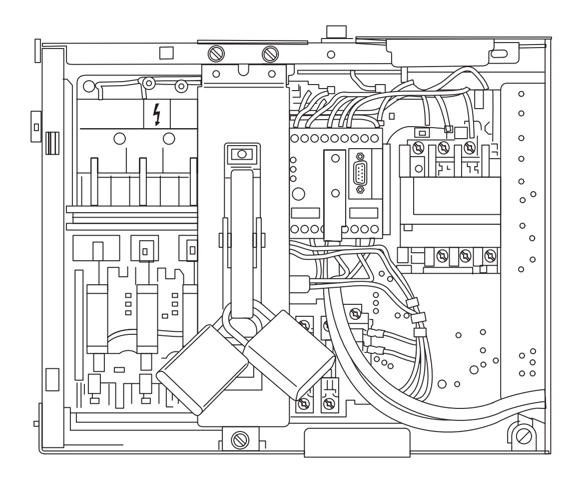

## Ground Clip

A copper clip on the side of the combination motor control unit engages the unit support bracket, grounding the unit to the motor control center at all times. An optional vertical bus stab is mounted on the unit when a vertical ground bus is used.



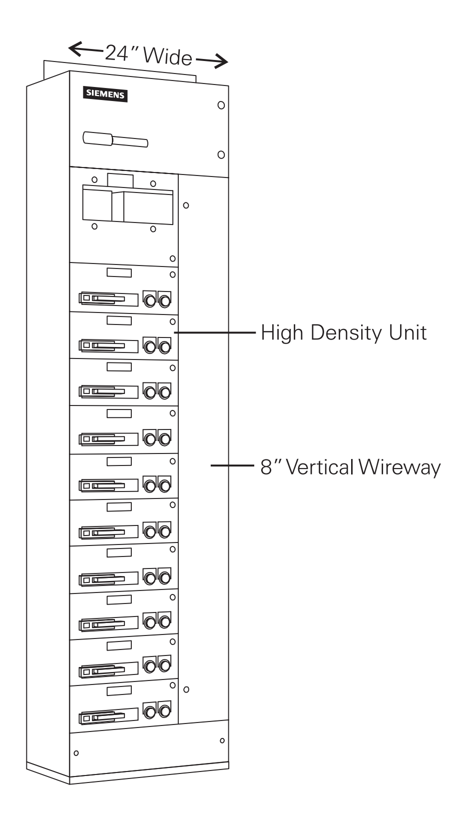
## Locking

The disconnect operating handle can be locked in the “OFF” position with up to three padlocks.



## High Density Units

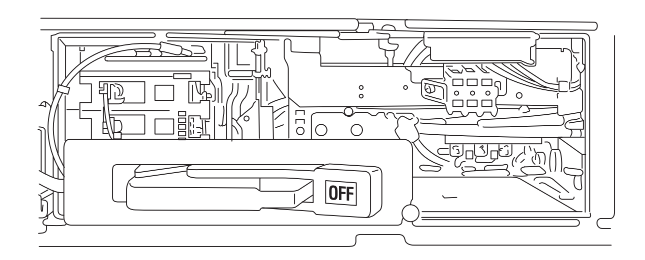
TIASTAR is also available with high density units. High density units are 6” tall. A maximum of 12 high density units can be installed in 72” of vertical space. High density combination motor control units are available in NEMA size 0 (5 HP) and size 1 (10 HP). To compliment the high density unit, a 24” wide structure is available with an oversized (8” wide) vertical wireway. While the 24” wide structure allows for the increased quantity of wires typical of high density applications, they are not required when high density units are used.



## Combination Units

High density units have many of the same features as the full size units. The disconnect operating handle is mounted sideways. When Type B or C wiring is specified, a swing-out terminal block is supplied.

The motor starter is located behind the terminal block. The circuit breaker is located behind the operator handle. A unique "swing out" feature permits components to swing out of the unit for easy inspection or maintenance.



# Information Needed to Order MCCs

When ordering a motor control center several questions need to be answered. The following information will be useful.

- Voltage, frequency, number of phases, and available fault current of power supply
- Incoming power requirements (main circuit breaker, main fusible switch, main lugs only, or splicing to existing MCC)
- Amp rating of the horizontal bus and finish material (tin or silver)
- Voltage rating and source of control power
- Size, type (aluminum or copper), number per phase and location of incoming cables or busway and outgoing cables
- Enclosure
  - Type, finish
  - Accessibility (front, rear, or both)
  - Clearance for door swing
  - Restrictions on height, width, and depth
- Horsepower rating and motor design of motors to be controlled
- Ampacity of feeder tap units and unit disconnect devices
- Type of disconnect for units: thermal-magnetic, instantaneous trip, or fusible
- Ground bus requirements
- Types of starting method of combination motor-control units, such as FVNR, FVR, 2S1W, 2S2W, PW, or RVAT
- Type of control circuit for units

- Service entrance requirements
- Vertical bus requirements (finish, isolated/insulated, amp rating)
- Class and Type of wiring
- Additional equipment requirements (transformers, panelboards, transfer switches, PLCs, etc.)
- Preferred layout of units
- Special features, codes, or restrictions
- Customer specifications
- Drawing requirements

**Review 6**

1. The maximum height of an optional pull box for the TIASTAR is ____________ inches.

2. A maximum of ____________ high density units can be mounted in 72" of vertical space.

3. High Density units are available in NEMA size ____________ and NEMA size ____________ .

4. The horizontal power bus is located in the 12" of ____________ space.

5. Isolated and insulated vertical bus design is standard for ____________K bus bracing and all back-to-back structures.

6. Vertical space for the TIASTAR motor control center is ____________ inches.

7. The horizontal ground bus for TIASTAR motor control centers is typically located in the ____________ 6" of space.

8. TIASTAR back-to-back structures are ____________ inches deep.

# Review Answers

| | |
|---|---|
| **Review 1** | 1) d; 2) TIASTAR; 3) 3; 4) 2. |
| **Review 2** | 1) Underwriters Laboratories; 2) National Fire Protection Association; 3) 200,000; 4) 430-94. |
| **Review 3** | 1) B; 2) 80; 3) B; 4) A; 5 ) B. |
| **Review 4** | 1) 10; 2) 3; 3) 200; 4) f; 5) SIRIUS and SIKOSTART. |
| **Review 5** | 1) 2000; 2) 100,000; 3) IP14; 4) a=A, b=B-t, c=B-d, d=C |
| **Review 6** | 1) 24; 2) 12; 3) 0 and 1; 4) top; 5) 100; 6) 72; 7) bottom; 8) 21. |

# Final Exam

The final exam is intended to be a learning tool. The book may be used during the exam. A tear-out answer sheet is provided. After completing the test, mail the answer sheet in for grading. A grade of 70% or better is passing. Upon successful completion of the test a certificate will be issued.

**Questions**

1. ____________ is the trade name for a Siemens motor control center.

   a. SIKOSTART
   b. INNOVA PLUS
   c. SAMMS
   d. TIASTAR

2. Article ____________ of the *National Electrical Code*® requires overcurrent protection for MCCs.

   a. 430.94
   b. 240
   c. ICS-1-322
   d. 430.97

3. Which of the following is <u>not</u> a part of the NEMA definition for motor control centers?

   a. Principally contains branch circuit protection
   b. Floor-mounted assemblies
   c. Common horizontal bus
   d. One or more vertical sections

4. The standard height of a vertical section is ____________ inches.

   a. 72
   b. 40
   c. 90
   d. 20

5. The maximum shipping width of a motor control center assembly is ____________ inches.

   a. 60″
   b. 80″
   c. 90″
   d. 120″

6. According to *NEC*® Article 430.97, there should be a minimum distance of ____________ inch(es) of clearance between a live bus and ground.

   a. 1
   b. 2
   c. 3
   d. 4

7. A Class 20 overload relay will trip within ____________ seconds when motor current is 600%.

   a. 3
   b. 10
   c. 20
   d. 30

8. ____________ is a motor protection device that is designed to work with PROFIBUS-DP.

   a. INNOVA PLUS
   b. SENSITRIP III
   c. FVNR
   d. SIMOCODE-DP

9. A NEMA size 3 controller is rated for __________ HP at 480 volts.

   a. 3
   b. 25
   c. 50
   d. 100

10. Motor control centers are rated for ____________ volts.

    a. 480
    b. 600
    c. 1000
    d. 1200

11. Up to ____________ 30 mm pilot devices can be mounted on the combination motor control unit door of a Siemens TIASTAR motor control center.

   a. 2
   b. 4
   c. 6
   d. 8

12. Siemens motor control centers are manufactured with a maximum temperature rise of ____________ over 40°C ambient.

   a. 25°C
   b. 50°C
   c. 65°C
   d. 75°C

13. Type B-t wiring can be used on starters up to size ____________ .

   a. 3
   b. 5
   c. 6
   d. 7

14. No terminal blocks are supplied on Class I, Type ____________ wiring.

   a. A
   b. B-t
   c. B-d
   d. C

15. Type ____________ wiring is not available on Class II motor control centers.

   a. all types are available on Class II
   b. A
   c. B
   d. C

16. The primary standards for MCCs are established by ____________ .

   a. ANSI, IEEE, IEC
   b. ANSI, NEC, IEC
   c. UL, IEEE, NEMA
   d. UL, NEMA, *NEC*®

17. TIASTAR high density units take up ____________ inches of vertical space.

   a. 18
   b. 12
   c. 6
   d. 4

18. Most Siemens plug-in combination motor control units use ____________ for quick bus connect and disconnect.

   a. pull-apart terminal blocks
   b. two-bolt, U-shaped clamp
   c. shelf-brackets
   d. stab clips

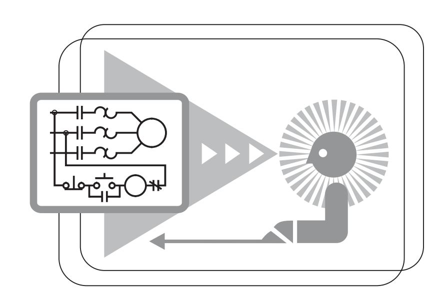
19. To remove a combination motor control unit from a System/89 MCC, the operating handle is placed in ____________ .

   a. On
   b. Off
   c. Park
   d. Tripped

20. ____________ will allow the use of branch circuit protective units in a motor control center provided their use does not make up a major portion of the motor control center.

   a. NEMA (ICS-2-322)
   b. *NEC*® (430.97)
   c. *NEC*® (430.94)
   d. UL (845)

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